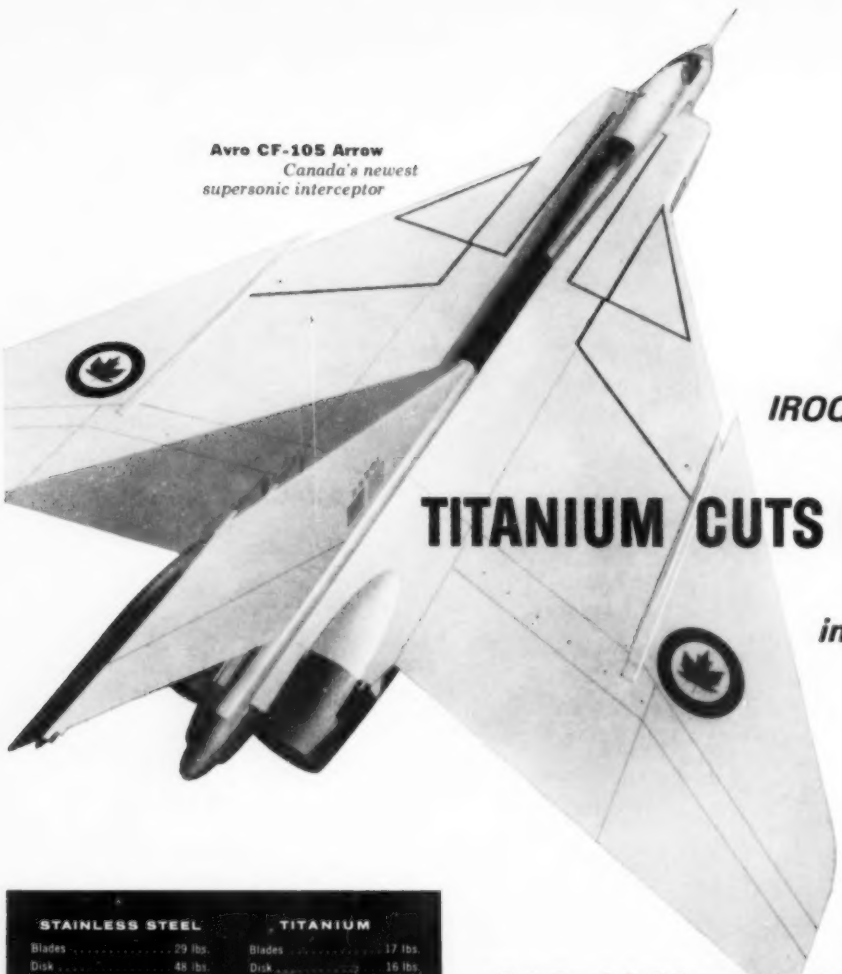
Metal Progress

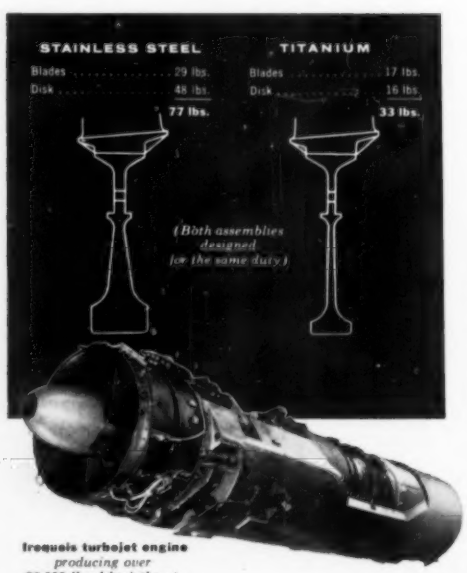


Avro CF-105 Arrow
Canada's newest supersonic interceptor

In the Arrow's twin IROQUOIS turbojets...

TITANIUM CUTS WEIGHT 57%

in compressor blade assemblies



Iroquois turbojet engine
producing over 20,000 lbs. (dry) thrust.

Twin Orenda-built Iroquois jet engines will speed the Avro Arrow through space at 20 miles per minute. In these advanced design turbojets, as in the aircraft structure itself, every pound of weight-saving becomes a vital consideration.

To Orenda designers, titanium's high strength-to-weight ratio proved a double bonanza. By using titanium in place of stainless steel for compressor blading, much lighter titanium disks could also be used. *Result: A total weight saving in the assembly of 57%* (see diagram). In addition, lighter structural members could be used, contributing further weight savings and improving performance.

Mallory-Sharon, in cooperation with Atlas Titanium, Ltd., produced many of the titanium alloys which help make possible the Iroquois' superior performance. These same technical and production facilities are available to you *now* . . . to assist you in using titanium's outstanding physical and mechanical properties to maximum advantage. Write us for information or technical assistance.

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Metal Progress

December 1958 . . . Volume 74, No. 6

Cover: The Christmas effect of the cover is provided by a micrograph of molybdenum crystals under polarized light at 500 ×. Shown at the 1957 A.S.M. Metallographic Exhibit; Charles Monroe, Detroit Testing Laboratory, Inc., metallographer.

Feature on High-Alloy Castings

High-Alloy Castings . . . Specifications and Properties, by Ernest A. Schoefer 95

Castings made from corrosion and heat resistant alloys are used under conditions where other materials would be destroyed by the action of the environment. Frequently referred to as stainless steel castings, the multiplicity of grades available is the result of the need to tailor-make alloys for the severe service applications in which the castings are employed. (Q-general, R-general; S22, SS, SGA-g, SGA-h, 5-60)*

Selection of Alloys for Heat Resistant Service, by R. A. Miller 98

Emphasis should be on minimum cost per operating hour, not on first cost alone. Proper choice of an alloy to do a given job depends upon several considerations. Among these are hot strength, resistance to hot gases, hot and cold ductility, resistance to carburization and thermal fatigue. (Q-general, 17-57; SGA-h, SS, 5-60)

Selection of Alloys for Corrosion Resistant Service, by W. T. Bryan 102

The corrosive environment should be studied for oxidizing or reducing characteristics, temperature or influence of contaminants. Other factors include mechanical properties and metallurgical structure. (Q-general, R-general, 17-57; SGA-g, SS, Ni, 5-60)

Data Sheet

Corrosion and Heat Resistant High-Alloy Castings 96-B

Standard designations, chemical composition ranges, mechanical properties, corrosion resistance, typical uses and other information which will help in selection of the right cast alloy for high-temperature parts.

Engineering Articles

What Carbon and Alloys Do for Iron Powder, by S. R. Crooks 68

New uses for powder metallurgy parts in structural applications subjected to high loadings promise to be opened up by iron powder containing alloy and carbon additions. Powders are soft and easy to briquet; parts develop high strength with short sintering time and simple heat treatment. (H12n, H-general; Fe-a, ST)

No Waiting in This Heat Treat Line, by Leo N. Everitt and Clarke C. Sykes 74

In *Metal Progress* for June 1958, Timken's plant at Bucyrus, Ohio, for automatic production of 27,000,000 roller bearings a year was described. Recently, the company unveiled its Columbus, Ohio, plant for railroad roller bearings. Here, as at Bucyrus, much of the success of automatic production is credited to a completely mechanized operation for carburizing and hardening. (J28g, W27g, 18-74, T7d; ST)

Ultra-Pure Metals Produced in Electron Beam Furnace, by T. C. DuMond 84

Electron melting method, combined with efficient vacuum system and cold crucible casting, reduces impurities to extremely low levels. (D5k, 1-52, 1-73)

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**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*

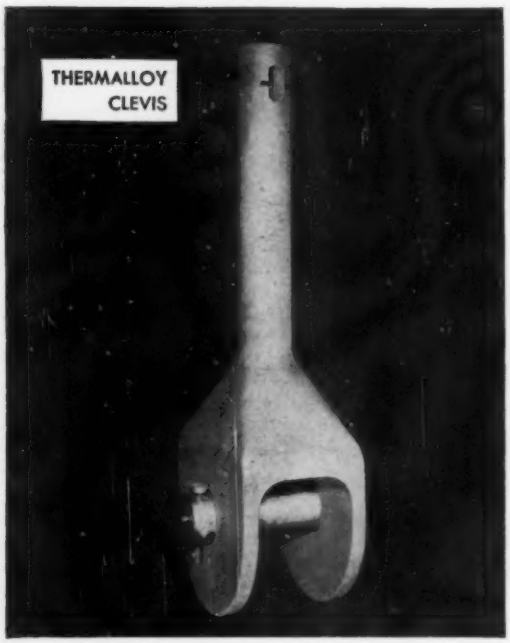
Thermalloy clevis design simplifies the heat treatment of large forgings

A manufacturer of large forgings uses the Thermalloy* clevis to heat-treat forgings weighing 30,000 to 74,000 pounds. The heat-treatment cycles range up to 300 hours with a maximum temperature of 1850°F.

Engineers from Electro-Alloys and the manufacturer working together developed the clevis for this heat-treating operation. The original lifting rig weighed four times as much as the Thermalloy clevis that replaces it. This reduces the total weight the crane must support in the furnace. The Thermalloy clevis simplifies lifting the forging by eliminating the wedging adjustment. Further, it eases the problem of positioning the forging in the furnace.

For advanced heat-resistant alloy-casting design service, contact your local Electro-Alloys representative or write: Electro-Alloys Division, American Brake Shoe Company, 90312, Taylor St., Elyria, Ohio.

*Reg. U. S. Pat. Off.



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Metal Progress

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High-Temperature Metallurgy Today, by L. P. Jahnke and R. G. Frank 86

Last month the authors discussed the mechanisms for strengthening alloys which have resulted in improved elevated-temperature materials. This installment carries these considerations into work on developing improved superalloys and refractory metal compositions. Properties of some of our best superalloys are given and future performance predicted. (Q-general, 2-62; SGA-h)

A New Direct Reduction Method, by M. J. Udy and M. C. Udy 92

Partial reduction of ore by soft coal in a rotating kiln, followed by smelting in an electric furnace, produces iron for further refining. Carbon can be controlled in a 0.2 to 3.5% range, and no special ore preparation is needed. (D8j)

Resistance Welded Tube Joints in Heat Exchangers, by J. J. Mueller 106

Resistance welded tube joints, metallurgically sound, uniform, and capable of resisting severe thermal shock cycling, have been produced in Inconel, stainless steel, and several other nickel-base alloys. (K3; SS, Ni-b, 4-60)

How to Avoid Hydrogen Pickup in Descaling Titanium Alloys, by Q. D. Wheatley 112

Immersion time in the titania-modified hydride bath should be as short as possible. Optimum conditions for descaling the hydrogen-sensitive 5 Al-2.5 Sn titanium alloy are obtained with a molten caustic bath containing 0.4 to 0.6% NaH, 0.35% TiO_2, and 10 to 20% Na_2Co_3 for 30 to 60 sec. at 610 to 645° F. (L 12n; Ti-b)

An English Turbogenerator Explodes, by Tom Bishop 114

The turbogenerator accident at Calder Hall atomic power station was not due to internal defects in forged components (as have plagued American power stations) but to overspeeding caused by nonfunctioning safety valves. (A7p, W11k, W11p)

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Atomic Energy for Space Propulsion, by Arthur W. F. Green 80

Based on information in "Hearings Before Joint Committee on Atomic Energy, 85th Congress", Jan. 22 to Feb. 6, 1958.

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Book Review

A Two-Volume Introduction to Physical and Process Metallurgy, Reviewed by John A. Shandley and Walter J. Kinderman 116

"Basic Metallurgy", edited by A. W. Grosvenor and written by a large number of authors, was designed as a textbook for a two-year adult education program sponsored by the Philadelphia Chapter ASM at Temple University. How well it served its purpose is attested by its adoption for other educational programs.

Digest of the Month

Tempered Alloy Martensites, by Peter Payson 138

Campbell Memorial Lecture at the ASM Annual Meeting on Oct. 29, 1958. Red hardness in high speed toolsteels is a function of alloy carbide content which, in turn, depends on composition of the steel.

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Metallurgical company—Called in to help settle a debate between plant engineers and safety department about where to put a large NH_3 tank, Herb Kerr's experience helped influence final decision. Later Kerr put in a 16-hour day helping to unload first tank car and get equipment running properly.

Big chemical company—Problem: to recover NH_3 used as a solvent. Although customer preferred not to reveal full details of process, Kerr and George Cleek, Allied specialists, were able to devise for them an economical method for purification and recovery.

New manufacturer—Wanted to make household ammonia. Needed help to get started. Kerr conferred with Gar Ellis on laboratory test before suggesting equipment and recommending a supplier of an additive which was known to give the right degree of cloudiness.

Chemical specialty company—Small, new at using NH_3. Bought some war surplus tanks, ran into problems, called Allied. "Zeke" Sziklas responded. Checked equipment they had, recommended additions, lined up contractor to install.

Paper mill—was considering ammonium bisulfite pulping. Allied worked out complete plans for NH_3 equipment required. Herb Kerr checked with "Westy" Westlake of engineering research before proceeding on trip to be on hand at startup—and for another three days—to make sure operations would continue smoothly.

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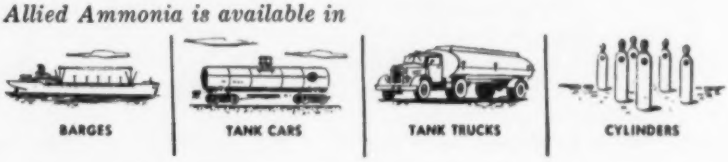

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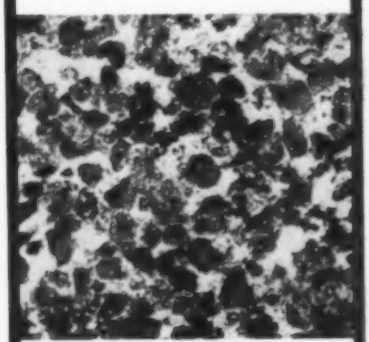

Photo-micrograph of sprayed coating, showing high tungsten carbide (dark particles) concentration. Mag. 50x – actual size of area shown, approx. .040" x .040". (Photo courtesy Sam Tour & Co., Inc.)

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Press Breaks...

AS WILL BE UNDERSTOOD by those who read the "Critical Points" in this issue, the Editor-in-Chief has not been at his desk too much during the preceding month, spending two weeks in the West (El Paso, Tex., and Richland, Wash., with stopover in San Francisco).

El Paso, particularly, evoked some nostalgia, for he was raised in Pueblo, Colo., the site of the most northerly Mexican settlement, and as a boy he traveled up and down the Front Range – in fact all over Colorado and New Mexico, either on horseback or on railroad trains, much of it narrow gage. (His father owned a weekly newspaper, and the railroads paid for their advertising in transportation!) As in Santa Fe and Albuquerque, only the plaza, the cathedral and small parts of the old town look at all familiar in El Paso. When you are whisked across semidesert at 70 miles per hour in a motor car, you can hardly imagine the toilsome journey across the well-named Dead Man's March, when the Spaniards pushed north from El Paso. In comparison, an afternoon's flight putting you in San Francisco is simply miraculous.

Following this, with a week in between, came the National Metal Congress and Exposition in Cleveland which kept all of us busy for a full week and more because the Seminar on Magnetic Properties of Metals was held on Saturday and Sunday preceding convention week. Another important event of the week was the Seminar on Residual Stresses, held Thursday, Friday and Saturday at Wade Park Manor, some miles from the Convention Headquarters. This was only the second such affair held under the program of "ASM of Tomorrow", approved by the Board of Trustees three years ago. Consequently it was in the nature of an experimental effort.

In place of being a series of papers by several authorities, the lectures, seven in all, were given by Prof. Richard Weck of Cambridge University, chairman of the Commission on Residual Stresses of the International Institute of Welding. In each session, he lectured for an hour; then after a coffee break the platform was occupied by two Americans, expert in some phase of the topic just discussed. Discussion from the floor then followed. The group was held together by serving luncheons and dinners in an adjoining parlor, so the intimate contact and resulting "bull-sessions", so desirable to resolve individual problems, were secured from the start. The 60 registrants were alert from beginning to end – no tardiness or absences!

Another "Art Critics Contest" was a popular feature of the ASM booth at the Metal Show. Ten *Metal Progress* covers (most of them to be used in some future issue) were hung on the backwall and visitors were invited to rate them in order of artistic appeal. A statistical evaluation of these ratings showed the general order of preference and also the person who came the closest to evaluating the covers in this order. He is R. A. Matasick, Titanium Div., Crucible Steel Co. of America, Midland, Pa., who has been awarded a dispatch case, in recognition of his artistic ability. Incidentally, ASM'ers showed good taste in their top choice because the most popular cover (see cut) is also the one awarded first prize in the Annual *Metal Progress* Cover Competition for students at the Cleveland Institute of Art. This also indicates the cultural level of Metal Show visitors! This first-choice cover – in full color – will adorn the February 1959 issue of *Metal Progress*.

As this goes to press we are busy with articles telling about developments in metallurgy and metal processing in many foreign countries for our special January International Issue. We believe you'll find some good ideas in it and a lot of interesting reading.

Merry Christmas and we'll see you in '59.

THE EDITORS

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Who cares what happens to METALS?

INVESTIGATING a de-carburization problem on a Tukon Hardness Tester. (Wilson Mechanical Instrument Div., American Chain & Cable)

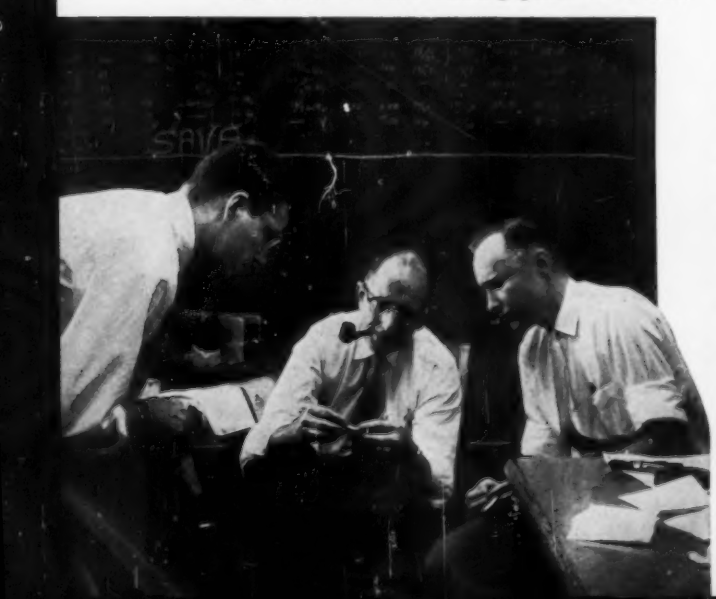
CHECKING the thickness of cadmium plating on a structural component by means of a Dermitron Non-Destructive Coating Thickness Tester. (Unit Process Assemblies, Inc.)

This trio of metals engineers, for example, at The Cleveland Pneumatic Tool Co., manufacturers of precision aircraft landing gear and a pioneering firm in a recent significant breakthrough on the problem of hydrogen embrittlement during electroplating operations on ultra-high strength steel.

Their responsibilities are determined by the raw materials of manufacture—steel, aluminum, and other metals—and the effects of manufacturing operations on these materials. Control of product quality begins with the supplier and extends through machining, grinding, welding, heat treating, plating, finishing and inspection. Moreover, the problems can be extremely complex. In the electroplating phase alone, the technique of cadmium plating actually affects the physical properties of the steel itself. And because of this phenomenon, it was necessary to develop new and fully instrumented plating processes to meet the unique characteristics of the ultra-high strength steels from which landing gears are made.

These men are experts—and yet they are students, or rather scholars. Daily they must seek new information to keep technically informed and effective. They are a part of a larger group of 30,000 metals engineers across the nation whose job it is to care what happens to metals and whose periodic text of information is METAL PROGRESS magazine.

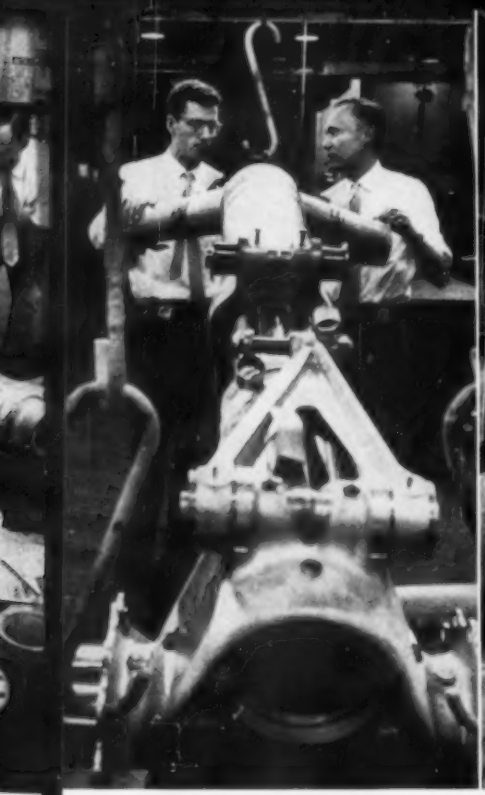
They learn from it... depend on it... contribute to it, because METAL PROGRESS meets their needs as the only publication, edited exclusively for them, concentrating solely on the engineering aspects of metals.



Examination of tensile test samples taken directly from production forgings brings together, L/R: D. J. Cash, Process Engineer; G. N. Barrett, Jr., Chief Metallurgist; H. F. Jordan, Jr., Chief of Processing and Documents.

Their job functions take them into separate yet co-ordinated responsibilities... Cash handles processing research, writes job process specifications and trouble-shoots for process improvement... Barrett supervises the metallurgical control of materials... Jordan oversees plant-wide engineering processing, including materials specifications.

Marjorie R. Hyslop
Managing Editor



DISCUSSING
the advisability of changing specifications for the type of cadmium plating employed.

OBSERVING
finish quality for conformance to specifications after flash-drying in an infra-red chamber.

EXAMINING
two different types of anodizing from the standpoint of design desirability.

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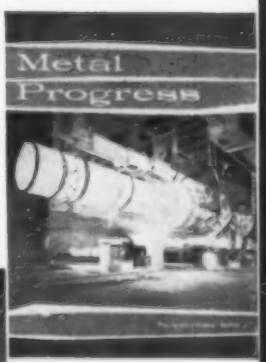

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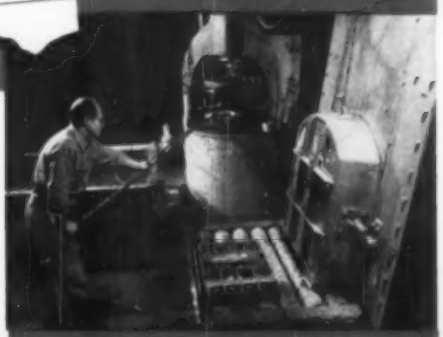

It takes more than equipment, no matter how modern, to perform the complex heat treating processes required today to achieve the property specifications of many metals.

Without the proper combination of operational skill and technical knowledge developed by years of experience, even the most mechanical, up to date equipment can become a menace to your product and a destroyer of your business.

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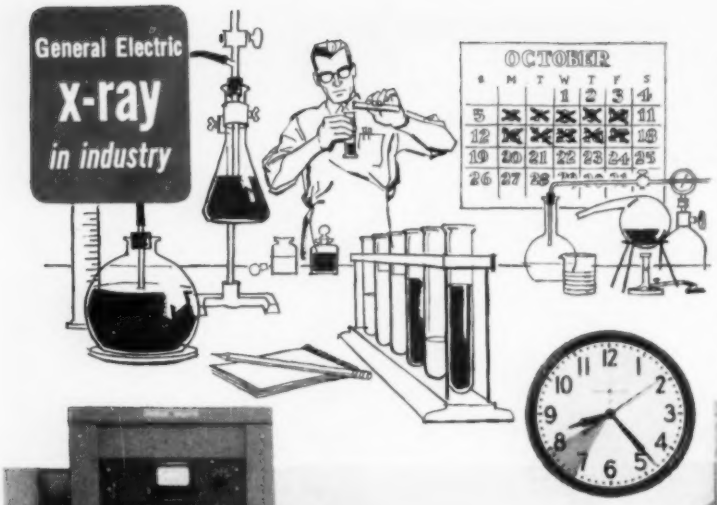

BEFORE: To control quality in the production of refractory metals from ores of widely varying purity, Fansteel Metallurgical Corp. used wet chemistry to detect impurities in tantalum and columbium. Problem: analysis dragged on for *two weeks* and even then was frequently subject to error.

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Truest expression of customer satisfaction is a re-order. And so pleased was Fansteel at the analytic speed of the G-E x-ray emission spectrometer at their North Chicago (Ill.) plant that they have installed a *second* production unit and a *third* at their research center!

In truth, we've yet to furnish one of these precision instruments where spectacular time-savings have not resulted. In metallurgy or non-metallics — this direct-measuring instrument takes large samples or small . . . supplies a permanent chart record.

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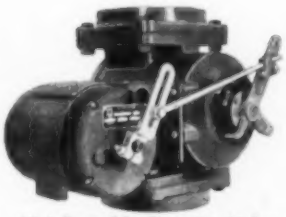

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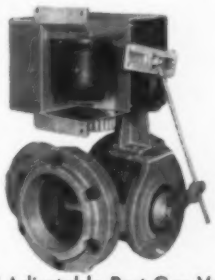

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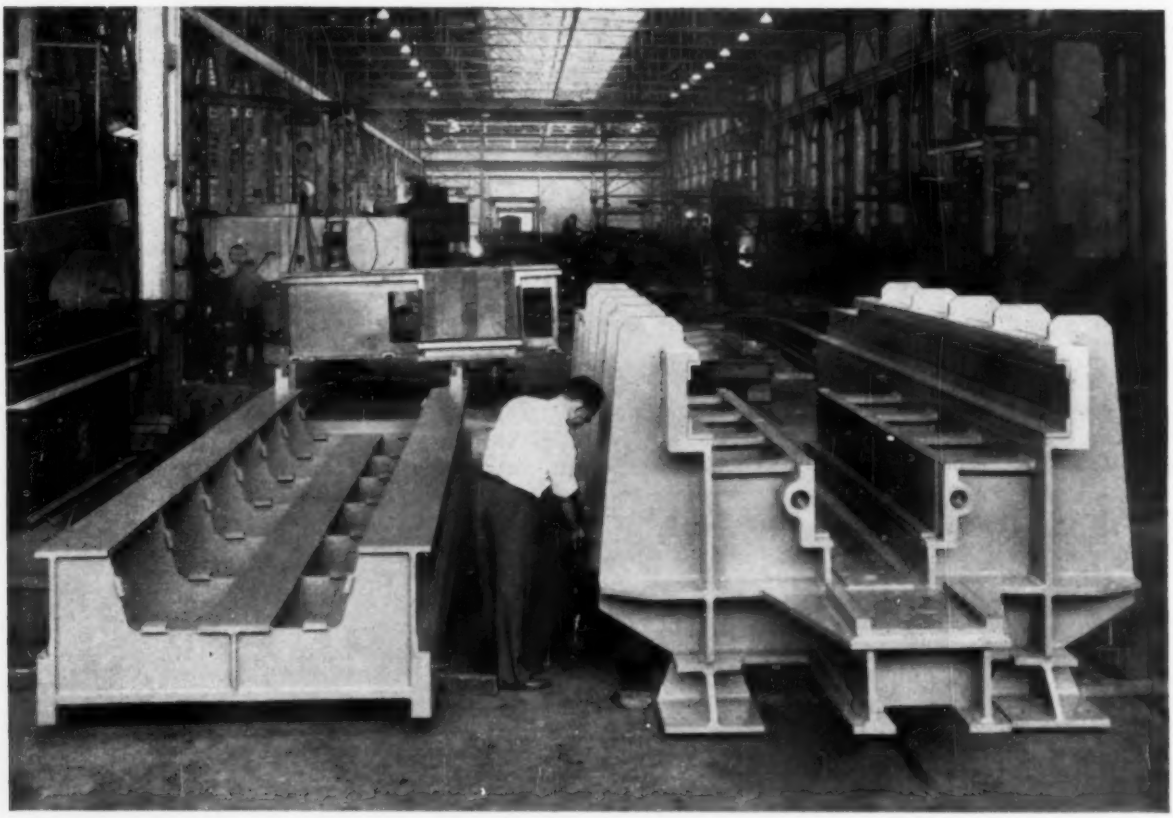
STEEL-WELD FABRICATION . . .



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The 40-Ton Frame and Carriage, illustrated above, are Steel-Weld Fabricated Parts of a loading device for a large extrusion press. These weldments are typical of thousands of Steel-Weld Fabricated units produced by Mahon for manufacturers of processing machinery, machine tools, and other types of heavy mechanical equipment.

When your design calls for weldments of any kind, you, too, will want to discuss your requirements with Mahon engineers; because, in the Mahon Company you will find a unique source for weldments or welded steel in any form . . . a fully responsible source with a long and enviable performance record, and unusual facilities for design engineering, fabricating, machining and assembling.

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The little booklet on alloy steels that grew into a textbook . . .

Quick Facts about Alloy Steels appeared for the first time in 1956, as a collection of reprints of a series of Bethlehem advertisements in metalworking magazines.

The small booklet was well received, and we kept adding more of the informative advertisements as we reprinted it to keep up with demand. Today, it has grown to 40-page size, and is in its Third Edition. More than 20,000 booklets have been distributed at the written request of executives, engineers, designers, and others, who have found *Quick Facts* to be an authoritative small textbook on the fundamentals of alloy steels. Here's what a U. S. Navy engineer wrote:

"*Quick Facts* is a small textbook of information—a booklet that has been needed for a long time. One of my associates and I had a metallurgical problem involving alloy steels. We just didn't have the information. A friend showed me a copy of your booklet *Quick Facts,* and there on one page, under the subject 'Determining Depth Hardness,' was just what we wanted to know!"

The current booklet contains reprints of the complete series of advertisements, on such subjects as, "What is an Alloy Steel?" "Effects of Elements," "Grain Size," "Heat-treatment," "Quenching Media," and others. It's written in concise, layman's language, from data compiled by Bethlehem's metallurgical engineers.

Would you like a copy of the *Quick Facts* booklet? Just fill out and send in the coupon.

PUBLICATIONS DEPARTMENT, ROOM 1030
BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

Please send me your "Quick Facts about Alloy Steels" booklet.

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Each of these men has earned the MEI Certificate. Each is a better "metals man" because MEI taught him more about metals

All the men in the photograph are MEI graduates . . . and, from the start, they had one important thing in common. They all work with metals. They can all personally benefit from a better, more current, knowledge of metals.

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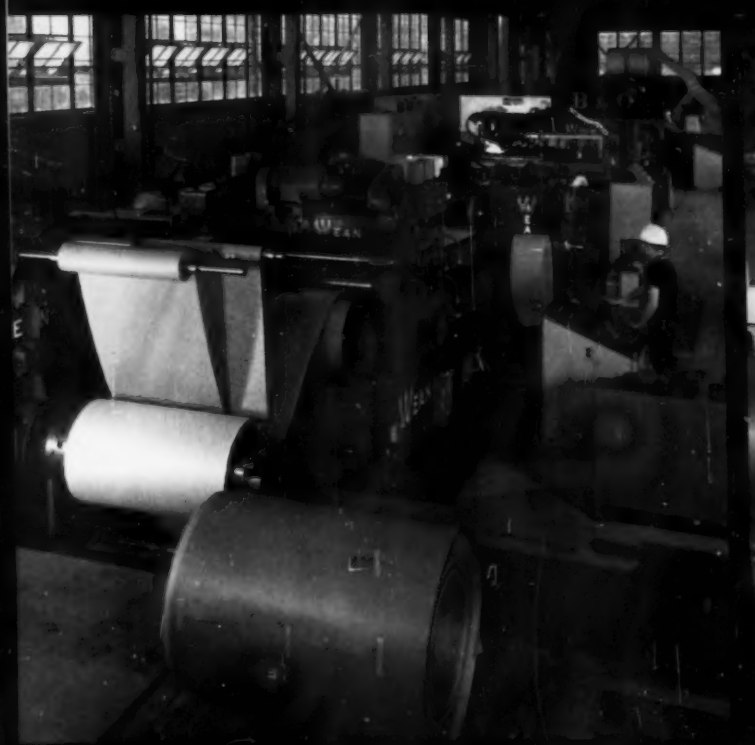
J & L's Completely New Stainless Mill . . .

designed and engineered to give you the fastest delivery on Quality Stainless Sheet and Strip

Now you can demand the quality you need and get the service you want from the most advanced stainless steel sheet and strip source in the industry. J & L's new Sendzimir Mill at Louisville, Ohio, is the result of years of planning by specialists to provide a new facility of such perfection that yield of the highest quality is assured.

J & L can now offer stainless sheet and strip to the most exacting specifications, producing stainless sheets to extremely close tolerances in widths up to 48 inches.

By efficient, flexible scheduling and adequate inventory support, J & L offers stainless steel buyers everywhere the fastest possible service.



▲ Coil Preparation Line for Incoming Hot Rolled Sheet

▲ The 54" Temper Mill

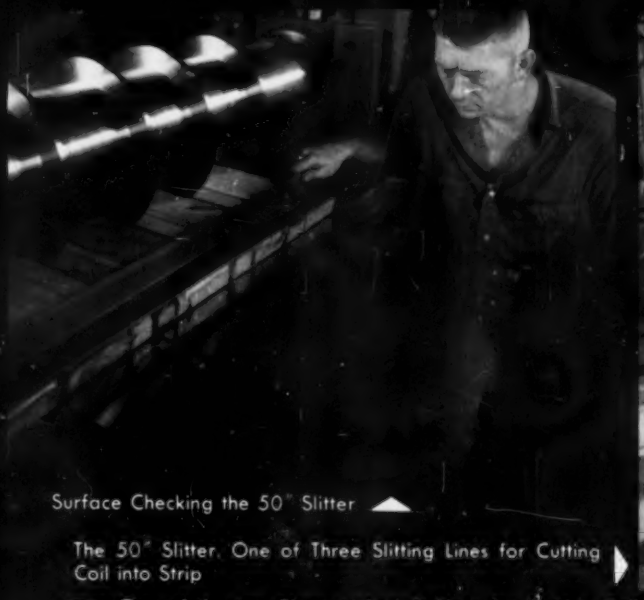
▼ Hot Anneal Furnace—Entry End

▲ The Sendzimir Mill

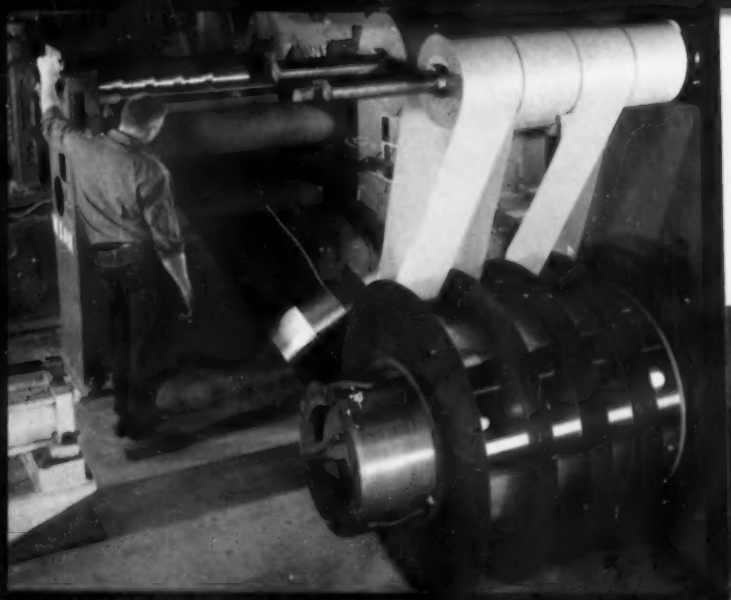
Interior View of the Intricate Mechanism of the Sendzimir Mill ▶

Scouring and Scrubbing Line ▼

▲ Cold Roll Anneal and Pickle Line—Discharge End



Surface Checking the 50" Slitter ▲



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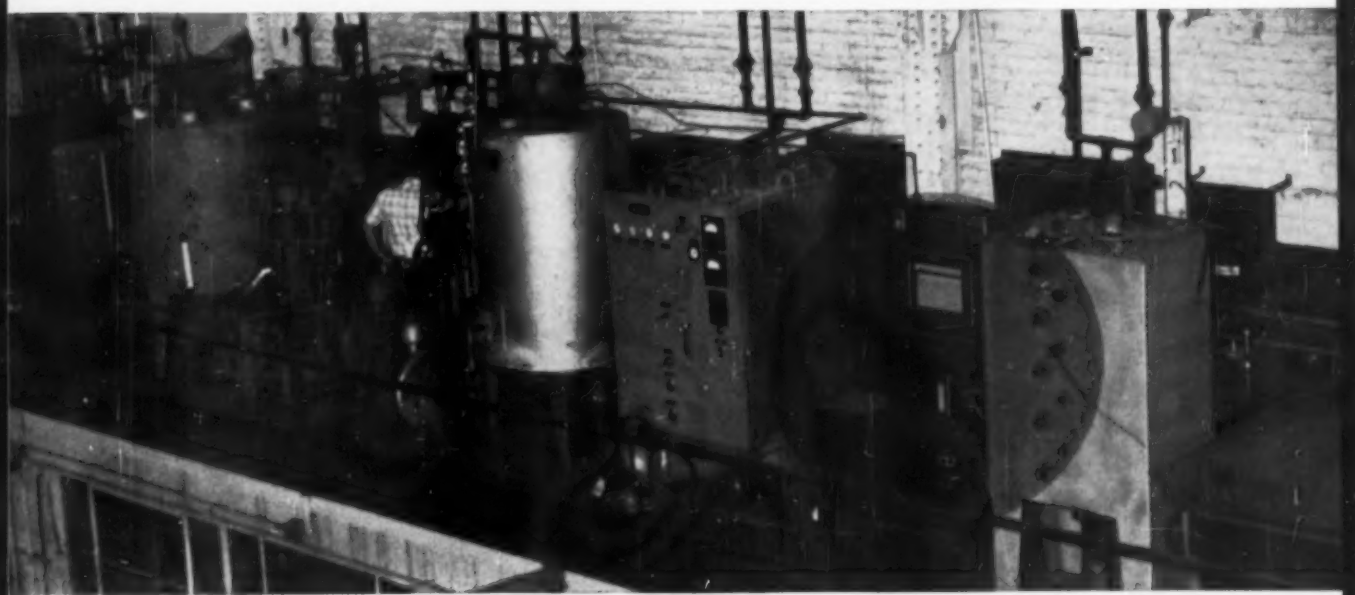
LITHO USA

M-S-A® LIRA Analyzers help control dew point of furnace atmospheres

You can prevent damaging oxidation and change in carbon content of metal surfaces by measuring water vapor content with M-S-A infra-red analyzers



Typical installation shows M-S-A LIRA Analyzer calibrated for suitable dew point ranges to determine carbon potential of the furnace atmosphere.

Heating metals like steel, copper, brass, etc., generally makes them chemically active with the atmosphere in the furnace.

Such atmospheric furnace action may damage the surface of the metal. It may cause scaling by oxidation. Or change in surface carbon by carburization or decarburization.

To combat this quality control hazard, many metallurgists are holding the carbon range to much closer tolerances with dew point control by infra-red analysis. And they're using M-S-A LIRA Analyzers to do the job. Safely. Reliably. Accurately.

Since water vapor is such an ideal absorber of infra-red radiation, M-S-A LIRA Analyzers are extremely well-adapted for controlling the dew point of a furnace atmosphere.

There are a number of M-S-A LIRAs installed in annealing operations of strip steel and special carbon steels, and also in pure hydrogen atmospheres where hydrogen brazing is taking place.

Principle of operation for the M-S-A LIRA is simple. The gas sample passes through a sample cell through which an infra-red beam is directed. This direct beam measurement eliminates the problems usually encountered in such analysis: getting water vapor to react with some salt, or cooling it to cause a frost on a mirror, etc.

An MSA Instrument Specialist will be pleased to discuss your specific problems with you. Write for information regarding your particular problems of atmospheric analysis and control.

The entire assembly of the M-S-A LIRA Analyzer is mounted on a self-supporting panel. All adjustments are easily made from the front of the panel.

INSTRUMENT DIVISION

Mine Safety Appliances Company

Pittsburgh 8, Pennsylvania

Memo on Metals

New Study Shows Crucible 56 Offers the Stability, Tensile and Yield Strengths Needed in 800—1000° F. Applications

A recent study considers three steels which show promise of solving the high temperature strength problems encountered in today's high speed flight.† These problems of maintaining structural strength at elevated temperatures are further complicated by the need for favorable strength/weight ratios.

Two of the steels are hot work types (Crucible 218 and 56) that are only now being considered for structural applications in aircraft. Crucible 56 is a relatively new steel, offering an unusually high level of stability at high temperatures. The chemistries of the three steels are as follows:

CHEMICAL COMPOSITION

Grade	C	CR	Ni	Mn	Mo	V	Si	Al
Crucible 56	.40	3.30		.60	2.75	.40	1.00	
Crucible 218	.38	5.20		.35	1.40	.50	1.10	
AISI 4340	.40	.80	1.80	.70	.25		.30	

Figs. A and B compare the tensile and yield strengths of the three steels at the exposure temperature. The curves show that both Crucible 56 and Crucible 218 proved superior in these tests. However, the hardness-tempering curve for Crucible 56 shows that it is more stable than the other analyses evaluated. Crucible 56 also offers higher hardness (and hence, strength) when tempered in the 1050-1100° F. range. As the comparisons indicate, it also has higher elevated temperature tensile and creep properties than Crucible 218, which is a conventional AISI type. In Fig. C, the isochronous (constant time) stress-strain curves illustrate the stability of Crucible 56 at the top of the service temperature range. With these curves it is possible to determine the stress at which creep becomes an important consideration.

For further details on Crucible 56 and other comparative data, send the coupon.

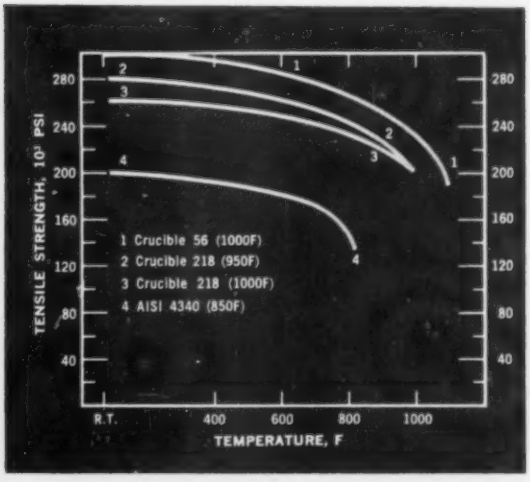


Fig. A. Tensile strength of various steels at exposure temperatures. Figures in parentheses are tempering temperatures.

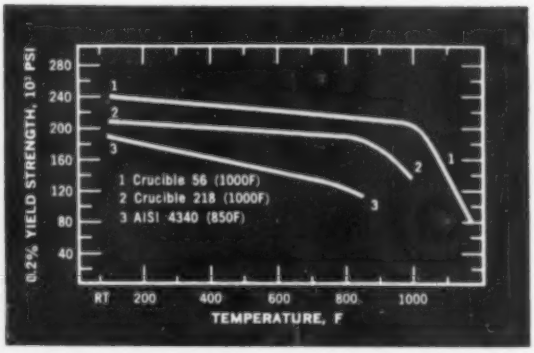


Fig. B. Yield strength (0.2% off-set) of various steels at exposure temperatures. Figures in parentheses are tempering temperatures.

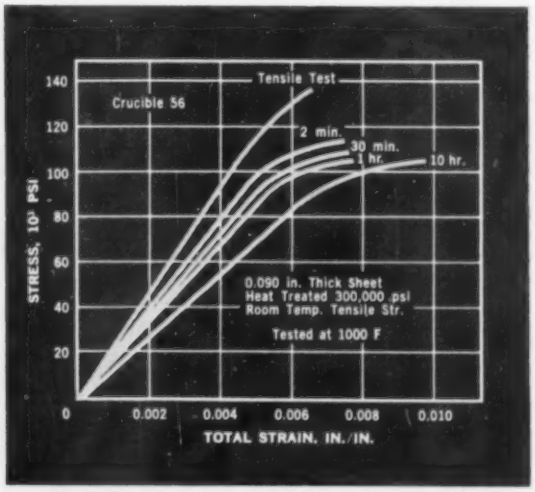


Fig. C. Isochronous stress-strain curves for Crucible 56 sheet show the outstanding creep properties of this steel which are higher than any other steel at 1000° F.

†Although this study considers only aircraft applications, data given here may prove helpful in designing turbines, chemical processing and nuclear equipment, and other equipment where service temperatures ranging from 800-1000° F. are required.

* high temperature strength
* vacuum melting
* cast properties of UHS-260

Compares properties of bearing steels produced by various melting techniques

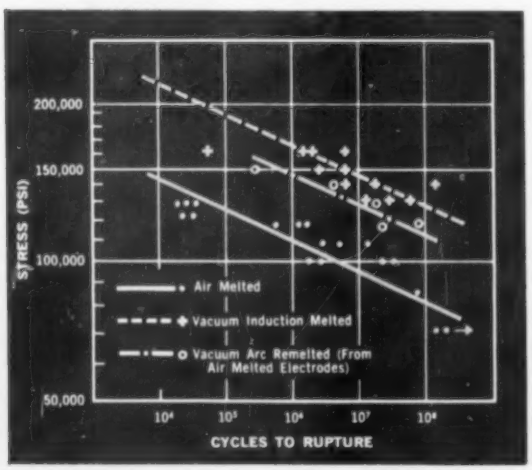
High vacuum technology has expanded considerably in recent years. The degree of improvement obtainable can be shown by comparing the properties of SAE 52100 produced by various melting techniques.

The following table gives gas content analyses of this chromium-carbon steel when produced by air melting (AM), air melting and vacuum arc remelting (AM + VAR), vacuum induction melting (VIM) and double melting (VIM + VAR):

Melting Technique	O(PPM)	N(PPM)	H(PPM)
AM	30	100	≤ 1
AM + VAR	7	70	≤ 1
VIM	5	3	≤ 1
VIM + VAR	3	3	≤ 1

Reduction in gas content is important, of course, because gases have varied detrimental effects on alloys. Oxygen increases transition temperature and forms various types of inclusions. Nitrogen effects aging, fatigue and stress rupture.

Similar improvement is obtained in cleanliness. (Inclusions strongly influence properties such as fatigue, impact and ductility.) Vacuum induction melted 52100 shows very small sulphide and oxide inclusions. Its background is extremely clean. Vacuum arc remelted 52100, made from air melted electrodes, also shows significant improvement over the air melted steel. Still further improvement is available with double melting.



Up to now, vacuum melted 52100 has been used mainly in bearings for jet engines, grinder spindles and instruments. It is credited with extending "B-10" life (the life at which 10% of the bearings fail) from 65 hours to 375 hours. Premature failures have been virtually eliminated. And the average number of production rejects of finished balls has dropped from 15% to 0.3%—savings that in some cases pay for the slightly higher cost of the vacuum melted alloy.

For more data on vacuum melted SAE 52100—or data on other vacuum melted ferrous and non-ferrous metals and alloys—send the coupon.

UHS-260 in cast form offers high strength with good ductility

New studies of the cast properties of UHS-260 should prove interesting to designers of structural parts for aircraft. In cast form at high temperatures, UHS-260 offers very high tensile strength with ductility equal to or better than transverse properties of the wrought form. Data from a preliminary report is given below. *For more complete information send the coupon.*

Grade UHS-260 Cast Properties —Preliminary Report

Nominal Composition

C	Si	Mn	Mo	Cu	Fe	Cr	Ni	V	Condition
0.35	1.50	1.35	0.30	—	Bal.	1.25	—	0.30	Hardened & Tempered

Mechanical Properties

	Test Temp °F.	Tensile Strength psi	Yield Strength psi	% Elong	% R.A.	Charpy Impact
Mean	−40°	265,000	218,000	6	10.5	7
High		268,000	226,000	6.5	15	8
Low		262,000	213,000	4	9	6
Mean	76°	260,000	217,000	4.5	12.5	7.7
High		265,000	241,000	6	16	8
Low		257,000	211,000	4	7	6
Mean	400°	266,000	191,000	5	7.3	11
High		269,000	205,000	6	10	13
Low		261,000	183,000	4	5	9
Mean	600°	237,000	162,000	9	18	11.3
High		240,000	172,000	10	23	12
Low		234,000	153,000	8	13	10
Mean	800°	200,000	147,000	9.6	29	12.3
High		232,000	179,000	13	42	13
Low		189,000	131,000	3	4	12

CRUCIBLE STEEL COMPANY OF AMERICA
Dept. EL09, The Oliver Building
Mellon Square, Pittsburgh 22, Pa.

Gentlemen:

Please send me the following:

1. Crucible 56 Data Sheet_____ Comparative Data_____
2. Data sheet on vacuum induction melted SAE 52100_____
3. Data on other VIM metals_____
4. Further information on the cast properties of UHS-260_____

Name_____

Title_____

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HOW CAN YOU USE THIS NEW TYPE OF

ArmaSteel®

Tensile strength, 105,000 • Minimum yield, 85,000 • Minimum elongation in 2", 2% • Brinell hardness 269-302, (3.5-3.7 mm)
Machinability 20% better than steel of same hardness!

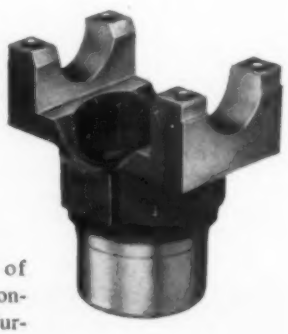
ARMASTEEL 88M has been developed to fill the automotive industry's needs for a material having increased wear resistance and high yield strength, yet at the same time retaining good machine characteristics.

ARMASTEEL 88M does not require heat treating and thus relieves customer facilities or eliminates capital expenditures. In many parts, distortion is a problem after heat treating. Parts made from ArmaSteel 88M can be machined without further heat treatment and still give good wear resistance.

This new castable metal is a pearlitic malleable iron which possesses substantially the same strength and the same wear characteristics as alloy steel forgings. Being a castable material, it has the two advantages of design flexibility and good machinability. Why 88M possesses these characteristics—and how it will fill the needs of American industry will be of interest to manufacturers and engineers in many fields . . .

PRODUCTION OF 88M—By accurately controlling the heat-treatment of ArmaSteel 88M in controlled atmosphere furnaces at 1750° for approximately 15 hours, all massive carbides are removed. This heat treatment is followed by closely controlled oil quench and tempering operations to provide a narrow range of hardness.

Universal Joint Yoke



Automatic Transmission Planet Gear Carrier

Surface hardening of ArmaSteel, if desired, does not require carburizing. Instead, flame-hardening, induction-hardening or simple immersion methods may be used. A surface hardness of 50 Rockwell C to 60 Rockwell C can be readily obtained. Wear-resistant properties in the hardened area are comparable and sometimes better than carburized steel, while the remaining sections retain their original toughness.

MACHINABILITY—In addition to performance characteristics, ArmaSteel offers good machinability. Carbon spots that are present in the Matrix of ArmaSteel allow the chips to break off readily, effectively reducing machining time and prolonging tool life. In comparative tests, ArmaSteel shows itself to be a more freely-machining material than steel bar stock or forgings of the same Brinell hardness.

Because of its ability to assume the shape of practically any molded cavity, 88M not only permits great

81

PEARLITIC MALLEABLE IRON?

88 M *developed by*

CENTRAL FOUNDRY DIVISION

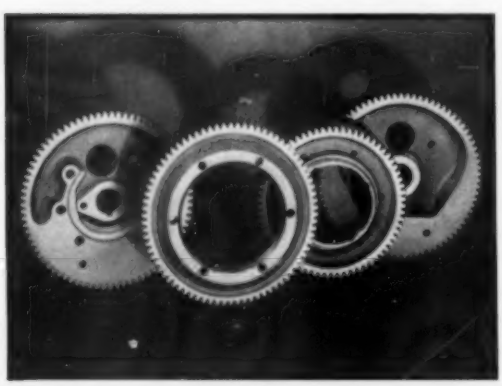
Transmission Output Shaft

freedom in design but also possesses certain inherent physical characteristics not present in forgeable alloys.

APPLICATIONS—ArmaSteel 88M is now being cast for automatic transmission planet gear carriers and universal joint yokes for leading automobile manufactures. Other interesting applications now in the testing stage include transmission output shafts, and diesel engine idler, balance and crankshaft gears.

Just what hundreds of other applications are in store for 88M is still anyone's guess. But the more one examines its characteristics, the more it would seem that it will fill many needs in many types of products and industries. In your products, for example, you may well see where 88M could both improve performance of components subject to great wear or great stress, and at the same time reduce final cost because of the economy in casting and the economy in a material with superior machining characteristics.

Diesel Engine Idler, Balance and Crankshaft Gears



CASTING—Parts are cast in ArmaSteel 88M, here at Central Foundry Division, in either standard green-sand molds or the newer, more precise shell-molds. In addition to 88M, Central Foundry Division produces castings, on a volume basis, in grey iron, alloy grey iron, malleable iron, and ARMASTEEL 84M, 85M and 86M.

Our research facilities and engineering staff are prepared to help you determine whether 88M or any of the other materials now being cast at Central Foundry will fill your needs or help you reduce your over-all product cost.

Write for your copies of our two comprehensive manuals, "ARMASTEEL" and "SHELL CASTINGS."

CENTRAL FOUNDRY DIVISION

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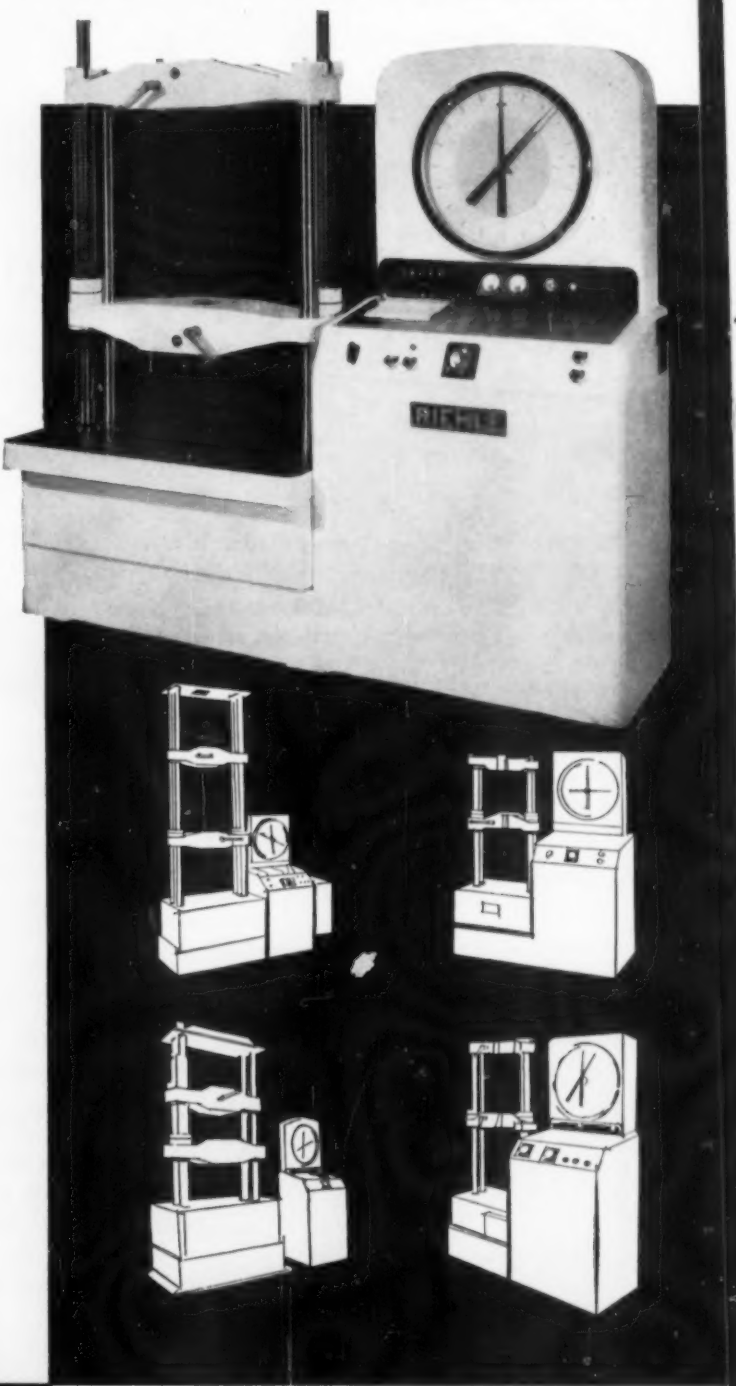
These universal testing machines

FACILITATE ALL MODERN RESEARCH AND CONTROL PRACTICES



Today's stringent testing requirements and demanding test schedules call for a universal testing machine with both the high sensitivity and rapid response of a Riehle. In addition, progress in modern practices of research and production control demand the broad flexibility that a Riehle provides.

For example, equipment and instruments now available bring programmed tests for both creep and relaxation and under vacuum furnace conditions into the scope of this machine's functions.

Hydraulic and screw power testing machines are available in capacities from 2,000 lbs. to 450,000 lbs. as standard. Riehle welcomes special application problems for testing equipment.

OTHER RIEHLE TESTING MACHINES: Creep and Stress-Rupture Testing Machines, Hydraulic Fatigue Testing Machines, Construction Materials, Impact, Brinell, Torsion, Horizontal Chain, Rope and Cable Testers, Portable Hardness Testers for Rockwell Readings, Etc.

Riehle TESTING MACHINES

A DIVISION OF

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APPLICATION and EQUIPMENT new products

Vacuum Treating

A new cold-wall vacuum treating furnace for sintering of powder metal parts compacted of materials with a very high melting point, such as tantalum, and degassing of components such as tungsten elements for electronic tubes, which require equally high temperatures, has been announced by F. J. Stokes Corp. Designed to operate at temperatures up to 4000° F., the new cold-wall furnace is suitable for both experimental work and for small scale production. It is of approximately desk-top height, 5 ft. 4 in. long and 4½ ft. wide. Within the vacuum retort, which is 20 in. in diameter and 20 in. deep, is a hot zone 3½ in. in diameter and 6½ in. deep, produced by a resistance-heated radiant cylinder. This hot zone is surrounded by a multilayer reflective shield, which in turn is surrounded by a water jacket.

For further information circle No. 1188 on literature request card, page 48-B.

Anodic Coating for Magnesium

A clear anodic coating for magnesium alloys that can be applied in less than 1 min. has been announced by the Dow Chemical Co. It is used under a lacquer or varnish for maximum corrosion protection. Lacquer or varnish tinted with commercial dyestuffs can be applied over the clear anodize to obtain a transparent effect. Clear anodize uses a 40-volt current. In 20% salt-spray tests, magnesium finished with clear anodize plus lacquer or varnish has passed 500 hr. with virtually no change in appearance. The anodic treatment can be applied to sheet, extrusions, die castings, sand castings and forgings.

For further information circle No. 1189 on literature request card, page 48-B.

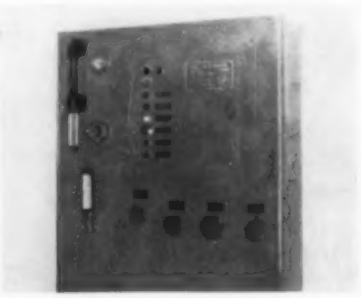
Inspection

A 58-lb. portable isotope machine that permits one-man radiographic inspection of industrial equipment has been announced by Picker X-Ray Corp. The new isotope machine can be operated with either iridium 192 or thulium 170. When loaded with an iridium 192 source of 10 curies, it radiates energy equivalent to that of a 600,000-volt X-ray machine; when 50 curies of thulium 170 are used, it radiates energy equal to that of a 125,000-volt X-ray machine.

For further information circle No. 1190 on literature request card, page 48-B.

Gas Generators

C. M. Kemp Mfg. Co. has announced two new models of inert gas generators in capacities of 500 and 1000 cfh. Discharge pressure of each is 1.5 lb. and a ½ hp. motor operates the smaller generator while a ¾ hp. motor operates the larger. The 500 cfh. unit uses 58 cu. ft. of natural gas and 22 cu. ft. of propane per hr. and the 1000 cfh. unit uses 115 cu. ft. of natural gas and 45 cu. ft. of propane per hr.



For further information circle No. 1191 on literature request card, page 48-B.

Impregnation System

General Vacuum Corp. has announced a new system for both vacuum and pressure impregnation of electrical components. The treating tank is 36 in. in diameter by 51 in. high. It is jacketed and insulated, and designed for operation at pressures from high vacuum to 250 psig. The hot-oil jacket heating system provides temperatures up to 600° F. Instrumentation and controls are actuated by sensing element in the oil-heated jacket or in the workpieces, or both. Other sizes are available for laboratory and production.

For further information circle No. 1192 on literature request card, page 48-B.

Copper Alloy

Scovill Mfg. Co. has announced a new alloy called OFHC + Sulphur copper, which is available in rod form only. Its composition is 99.75% Cu, 0.25% S. This new sulphur copper rod has a machinability rating of 90 based on a rating of 100 for free cutting brass; its electrical and thermal conductivity are approximately 96% that of OFHC or ETP copper. Its general corrosion resistance is comparable to pure copper. It may be used for parts which require machining and for headed, formed, rolled, pressed or swaged parts.

For further information circle No. 1193 on literature request card, page 48-B.

Vacuum Furnace

A new electric bell-type furnace with high vacuum and a temperature range up to 2700° F. has been announced by the General Electric Co. Cylindrical metal shields instead of brick insulate the inside walls. The radiation shields of heat-resisting alloy are arranged in several layers of concentric cylindrical shells on the inside walls of the heating chamber. The top and bottom have separated

SWIFT'S FLEXAL 2

Swift Development opens up New Opportunities for ANTI-FRICTION ACTION

Flexal[2] represents a family of "light" metallic stearates which were developed specifically to provide the metal processing industry with a highly heat resistant, water insoluble* processing lubricant.

They have exhibited excellent, effective and economical service life as anti-friction agents, are extremely uniform in composition and highly stable in storage and in use. Their versatility makes The Flexal[2] family highly adaptable to specific processing requirements.

Why not look over the general specifications with *your specific process* in mind? Our success with this dramatic new family may open a new avenue of ANTI-FRICTION ACTION for *you*. Write for details: SWIFT & COMPANY, Soap Department, 4115 Packers Ave., Chicago 9, Ill.

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titer range—10° C to 60° C
iodine number—max. to 95
melting point—150° F to 800° + F
storage life—completely stable
molec. weight—(approx.) 288 to 700

PHYSICAL

form—amorphous to powder
color—gray to white
odor—neutral
*solubility—versatile; Flexals can be either soluble or insoluble in water or solvents, depending upon need.

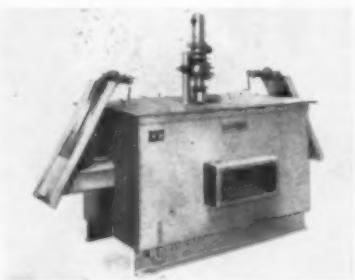
5-48-M

layers of alloy sheets in a horizontal position. The furnace is used principally for heat treating superalloys and refractory metals. The furnace casing is water-jacketed.

For further information circle No. 1194 on literature request card, page 48-B.

Tube Furnace

Hevi-Duty Electric Co. has announced a new line of molybdenum-tube furnaces, capable of operating at temperatures to 3000° F. Three standard sizes of single-end or double-



end furnaces are available. A reducing atmosphere is generally used to protect the elements. However, a second nonporous tube can be supplied to protect the work when a reducing atmosphere is not desired. Top of the furnace is removable for easy access to the elements.

For further information circle No. 1195 on literature request card, page 48-B.

Illuminator

A new surface illuminator which can be used for all standard magnifications on their micro-projector has been announced by the George Scherr Co. It picks up a design or contour

against an opaque background. The illuminator uses a 500 watt standard projection bulb. The mirrors are adjustable permitting use of the unit for all magnifications from 10 up to 100.

For further information circle No. 1196 on literature request card, page 48-B.

Steel Bars

A series of improvements in Stressproof steel bars have been announced by La Salle Steel Co. Yield strength is now 100,000 psi. in all sizes. New standard as-drawn tolerances range from 0.004 in. in sizes ¼ to 1½ in., 0.005 in. in sizes from 1½ to 2½ in., and 0.006 in. in sizes from 2½ to 3⅜ in. Through the addition of copper, improvements have been made in quality control and processing. Machinability in now approximately 85% compared with B1112.

For further information circle No. 1197 on literature request card, page 48-B.

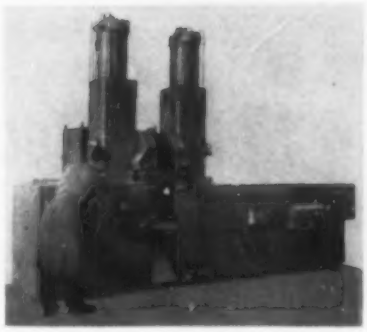
Nickel Plating

A new low-sludge anode for nickel plating of recessed surfaces has been announced by Hanson-Van Winkle-Munning Co. The new material corrodes evenly, producing minimum metallic and carbon sediment. No anode bags are required. The new alloy may be used in the form of auxiliary anodes to plate bright nickel areas of low current density.

For further information circle No. 1198 on literature request card, page 48-B.

Welding Machines

Asea Electric, Inc., has announced the importation of an automatic flash

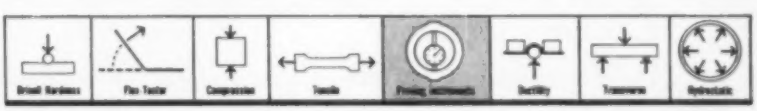


welding machine, equipped with hydraulic clamping and motor-operated upsetting. It has maximum welding section capacity of 40 sq. in. Automatic control is operated through welding temperature and slide distance. Uniform welds result when abutting surfaces are uneven.

For further information circle No. 1199 on literature request card, page 48-B.

Cleaning

A new method for cleaning and painting metal parts has been announced by the Du Pont Electrochemicals Dept. The process integrates vapor degreasing with application of paint by flow coating. The same solvent, nonflammable trichlor-



proving rings to measure any load

COMPRESSION or TENSION

Steel City offers two styles of proving rings which require no adjustment during use. The dial-indicator ring (illustrated) measures deflection in increments of 0.0001". Applied load or force is determined from a calibration report furnished with each instrument*. With this type of ring, even an inexperienced operator can repeat readings as close as 1/10 of 1%.

Optical-type proving rings, developed for the USAF, use a ruled scale and a high-powered microscope for readings in increments of 0.00002". Repeat readings as close as 1/20 of 1% can be achieved.

Compression and tension models are available in either style, with capacities up to 200,000 lb., all manufactured of special-alloy steel by experienced craftsmen. They are used for calibrating Brinell testers, testing machines and presses, and load cells, or for measuring applied loads.

* *National Bureau of Standards calibration report when desired.*

Write for literature, prices and name of nearest distributor.

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New Protection For YOUR Equipment— At Temperatures Up To 3300°F

ALUNDUM castables offer unusual advantages to all industries using high temperature installations*

Will fire continuously up to 3300°F. This Harrop gas-fired furnace, recently developed by the Electric Furnace Division of the Harrop Ceramic Service Company, Columbus, Ohio, is particularly applicable to the firing of ceramic oxide bodies. Norton ALUNDUM 33-I Insulating Castable selected for the inner lining of the furnace and its roof, provided completely satisfactory protection under repeated tests at highest operating temperatures.

The new Norton ALUNDUM Castables are made in two types: 33-I Insulating and 33-HD Heavy Duty. At temperatures up to 3300°F both types have been extremely successful in protecting high temperature processing — in many industries and many different installations.

ALUNDUM 33-I Insulating Castable is made up primarily of pure aluminum oxide bubbles, tiny and countless. Forming a network of air spaces, it assures excellent insulation, even at highest commercial temperatures.

ALUNDUM 33-HD Heavy Duty Castable is chiefly composed of dense grains of pure aluminum oxide. It is recommended for forming dense monolithic surfaces in many types of furnaces where high temperature conditions are particularly severe.

Both 33-I and 33-HD Castables are very easy to store, mix and use. With them you can cast simple or complex shapes quickly and economically, replace more expensive pre-fired shapes, and cut maintenance and replacement costs to very lowest. Ask your Norton Representative for details, and for the folder *Two Norton Castables.* Or write to NORTON COMPANY, Refractories Division, 332 New Bond Street, Worcester 6, Massachusetts.

*Trade-Mark Reg. U. S. Pat. Off. and Foreign Countries

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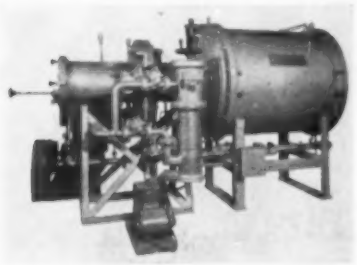
ethylene, is used for vapor degreasing and paint thinner. Then an air-drying paint is used, the parts are dry and ready for shipment when they are removed from the machine, since evaporation of the thinner occurs instantly. When a baking paint is used, the parts proceed immediately to the baking operation.

For further information circle No. 1200 on literature request card, page 48-B.

Vacuum Furnace

High Vacuum Equipment Corp. has announced a new horizontal, production furnace, capable of operating at temperatures up to 3000° F. at a vacuum of 5×10^{-4} mm. Hg. Furnace is designed for heat treating, annealing, brazing and sintering. It has a zone 12 by 18 in. resistance-heated by dual-zone molybdenum cage-type elements, and is insulated by a five-



layer molybdenum and stainless steel heat shield assembly. A loading-cooling zone, isolated from the vacuum chamber by a water-cooled vacuum gate valve, permits semicontinuous operation. The hot zone remains at constant temperature and under high vacuum at all times. Floor area required is 6 by 12 ft.

For further information circle No. 1201 on literature request card, page 48-B.

Conveyor

May-Fran Engineering has announced a new flat-top hinged steel belt conveyor for flush-with-floor and conventional above-floor mounting. Each belt link is precision formed, overlaps and interlocks to provide a smooth surface. Operating in a single, predetermined direction, the conveyor in flush-with-floor installations offers a moving sidewalk for heavy

warehouse loads while permitting crossing truck and personnel traffic with the belt in motion. It is engineered to prevent parts and tools from falling through and provide maximum safety.

For further information circle No. 1202 on literature request card, page 48-B.

Coatings

Dispersions of tetrafluoroethylene resins in a selection of binders which permit application of the plastic to heat-sensitive surfaces has been announced by Acheson Colloids Co. The Emralon series of dispersions can be cured at 300° F. or less. Preferably, application should be made with a spray gun of the external-atomizing type using air pressures of 35 to 50 psi. This is followed by air drying, or infrared or oven curing, depending on the Emralon used. The normal film thickness for lubricating purposes is about 0.6 mil. Where thicker coatings are desired, multiple passes can be made by the spray gun with air drying between passes.

For further information circle No. 1203 on literature request card, page 48-B.

High-Temperature Furnace

K. H. Huppert Co. has announced a new electrically heated high-temperature furnace for operation up to 3100° F. without protective atmosphere. Elements are oxide coated but

nonoxidizing and nonflaking. The furnace has automatic time-temperature run-up and automatic temperature control, and a double pivoted, swing-type door.

For further information circle No. 1204 on literature request card, page 48-B.

Controlled Atmospheres

A new instrument for control of furnace atmospheres has been announced by the Technical Products Div., Mine Safety Appliances Co. The Thermatron combines the thermal conductivity and thermal convection characteristics of a gas to selectively analyze one component in a gas mix-

WORD FROM Waukee...

HERE'S REAL HELP IN SELECTING FLO-METERS

A prominent engineer told us recently that the Waukee Flo-Meter Bulletin No. 204 was one of the most helpfully designed pieces of equipment literature in his files. Needless to say, this statement twanged our heart strings even though we planned it that way. Here are capacity tables for all the commonly used industrial gases and you can pick out the right meter size and price in a moment. Whether it's ammonia, helium, argon or rich exothermic, it doesn't matter —practically all the gases are there. Also there are complete dimensions including cutouts for panel mounting. Write to 5140 No. 35th St., Milwaukee 9, for your copy.

OUR MAN HILDING

July 30th, 1958 was a joyous day for this man. Here is this happy man on the Marysville, Michigan golf course with his two fine boys — John, his older boy just home from 2 years service in the Aleutians, and Neal who recently finished freshman year at Wayne University. And how does this man celebrate? On hole No. 3, 190 yards, he drops his tee shot into the cup for a hole in one! Who is this smiling man—it's Hilding Einar Ardahl, Mr. Waukee to the automotive industry of Michigan and hundreds of plants in Ohio. One time chief metallurgist for John Deere at Waterloo—then plant manager of a well known alloy foundry, here's a topnotch salesman who brings a wealth of background and experience to bear on his daily approach to customers' problems. Anchor member of the team is secretary Sadie, who also doubles as mother to John and Neal and wife to Einar, the name by which our man Hilding prefers to be known . . . and known he is—not only for an ace on the third at Marysville, July 30th, but top service as well the other 364 days of the year to Waukee customers. R.C.O.

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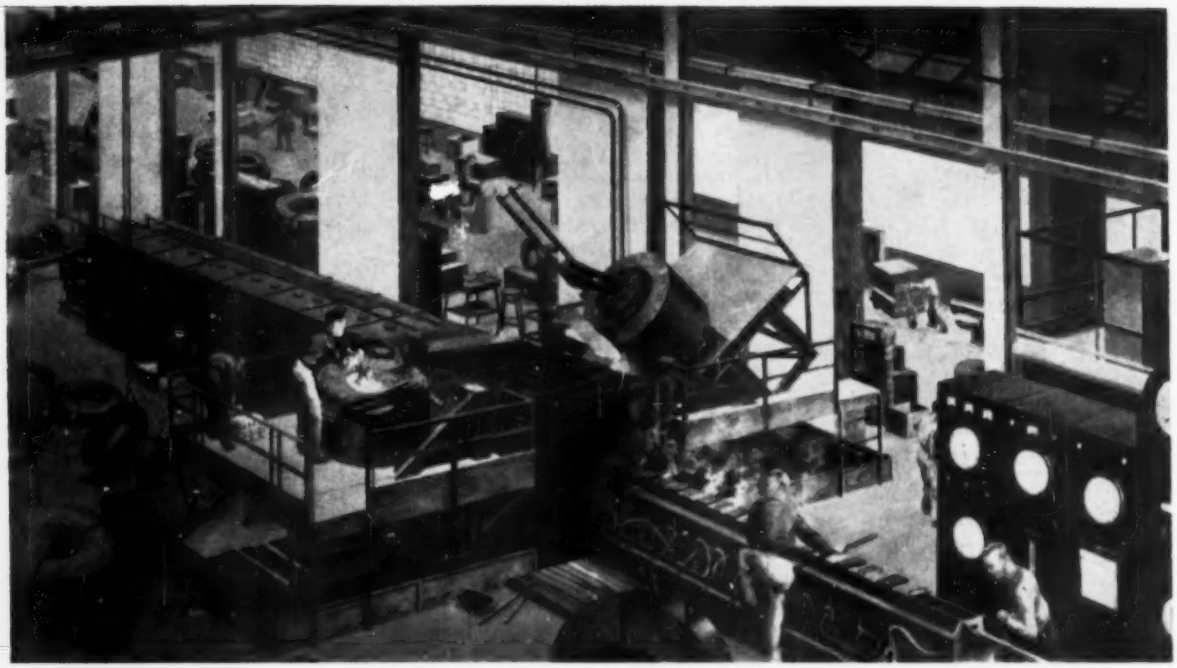
ROTARY-VANE COMPRESSORS
INDUSTRIAL WASHING MACHINES



60 CYCLE INDUCTION MELTING OF HIGH LEADED BRONZES

15 years ago, THE CLEVELAND GRAPHITE BRONZE COMPANY, division of CLEVITE CORPORATION, pioneered 60 CYCLE INDUCTION MELTING of bronzes with up to 35% lead. Special furnaces developed by AJAX for this difficult job are an important element in their unique continuous production line for steel-backed bronze bearing strip. 60 CYCLE INDUCTION MELTING furnaces resulted in substantial improvements and cost savings over gas-fired units used earlier for that purpose. Today, CLEVITE operates six continuous lines in this country and abroad with AJAX 60 CYCLE INDUCTION MELTING furnaces, producing enough strip to make 130 million bearings and bushings per year.

The heavy duty 60 cycle inductor developed by AJAX and pioneered by CLEVITE will attain a lining life of one year with bronzes of substantial lead content. Electromagnetic stirring assures uniform alloy and close temperature control. Compared to externally fired equipment, metal loss savings run into many thousands of dollars per year. Recently, several large producers of leaded bronze castings converted their foundries entirely to 60 CYCLE INDUCTION MELTING.

While this is one of the most difficult metals to handle, the advantages of 60 CYCLE INDUCTION MELTING stand out today wherever copper alloys are melted. As specialists in 60 CYCLE INDUCTION MELTING, we have developed furnace types to best fill each application.

AJAX USA

ENGINEERING CORPORATION

TRENTON 7, NEW JERSEY

60 CYCLE INDUCTION MELTING

Associated Companies: Ajax Electrothermic Corporation Ajax Electric Company

ture. Applications include measurement of hydrogen in furnace atmospheres; and measurement of hydrogen, carbon monoxide and methane in mixtures of these three gases with air or nitrogen.

For further information circle No. 1205 on literature request card, page 48-B.

Tool Material

A new ultra-hard steel-cutting tungsten carbide has been announced by Allegheny Ludlum Steel Co. CA-604 combines high-velocity finishing with light to medium feeds. The new grade contains titanium and tantalum carbide in the form of mixed crystal.

For further information circle No. 1206 on literature request card, page 48-B.

Steam Cleaner

A new, heavy-duty steam cleaner has been announced by Circo Equipment Co. Automatic controls operate the machine; even mixing of the cleaning compound is automatic. The

new units are available in two capacities: model 275 operates at 1½ hp. on 110 volts; model 360 at 3 hp. on 220 volts. Fuel capacity of both is 15 gal.; soap capacity, 15 gal. of concentrated solution.

For further information circle No. 1207 on literature request card, page 48-B.

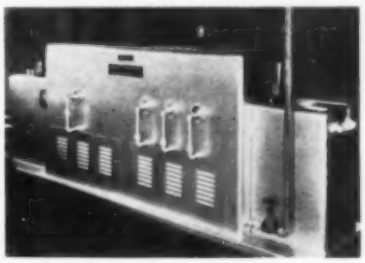
Finishing Compounds

Five new barrel finishing compounds have been announced by Almco Div. of Queen Products, Inc. No. 407 is an alkaline, powdered composition used in cleaning, brightening and grinding ferrous parts. Supersheen No. 408 is a powdered grinding compound with a silica flour base for use with all types of metals and alloys. No. 410 is an alkaline compound designed for light deburring and coloring cycles on ferrous metals. Supersheen No. 412 is a concentrated burnishing compound with tallow and oil soap base for use with all steel and chip medias on ferrous and nonferrous metals in either submerged or standard equipment. 501R is a concentrated mild alkaline compound for inhibiting rust on ferrous metals.

For further information circle No. 1208 on literature request card, page 48-B.

Annealing Brass Stampings

A continuous furnace to anneal brass stampings between draws has been announced by the Waltz Furnace Co. It is fired by eight gas burners with individual mixers. The

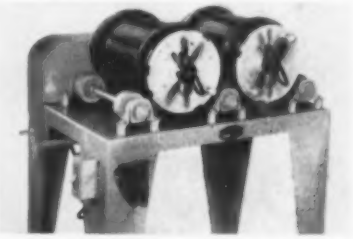


combustion blower, control valve, gas regulator and variable drive mechanism are mounted within the casing. The temperature control instrument is at the left on the loading section. Continuous annealing furnaces are built in various sizes and for different applications. They may be open-fired or controlled-atmosphere, full-muffler type.

For further information circle No. 1209 on literature request card, page 48-B.

Finishing Barrels

A new barrel finishing machine has been announced by Globe Barrel

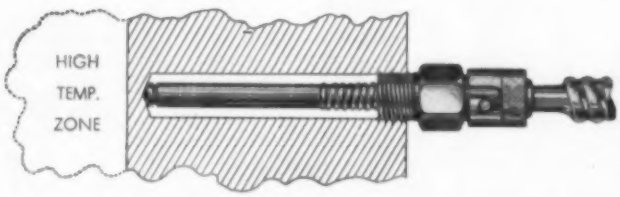


Finishing Equipment Div. of Casalbi Co. A one piece pressure-molded rubber barrel is driven on rollers. The cover is aluminum and is detached with a few turns of the handle. When the handle is locked in position, the barrel is watertight. Inside the barrel are three integrally molded ribs to assist in the agitating of parts.

For further information circle No. 1210 on literature request card, page 48-B.

Spring-Loaded Thermocouples Assure Dependable Contact

Field-Proven By Many Years' Successful Use



You always get fast, dependable response from T-E's miniature bayonet thermocouples because (1) spring-loaded hot junctions are always held in tight contact with the measured surface—regardless of expansion and contraction, and (2) the 'couples themselves are extremely sensitive to temperature changes. They are widely used with cylinder heads, extruders, heat transfer lines and other similar applications. Adapters of different lengths permit use of one thermocouple to measure temperatures at many different depths. Specially designed, patented, pipe-clamp adapters are also available. Bayonet-lock caps provide quick, easy removal. Lead connections are supplied straight or with 45° or 90° angles. All probes and adapters are of Stainless Steel. Available in C-C, I-C and C-A.

Write for Bulletin 2-H

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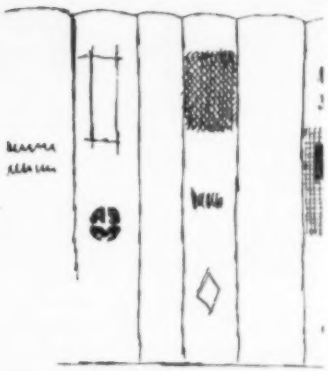

"THE METAL MOLYBDENUM"

A new and comprehensive book giving thorough coverage of the metal molybdenum. Includes properties, powder metallurgy, melting, working, fabricating, joining, coating and protection against oxidation. Red cloth binding—696 pages—6 x 9—538 illustrations—$12.50. NEW.

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Reviews high points of all plenary session talks and gives complete reports on special events. 240 pages—vividly illustrated—cloth binding—$5.00.

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Twenty-four design and processing sections prepared by twenty-two ASM technical committees. 200 pages—326 illustration, 155 tables, cloth binding—ASM members, $4.00—non-members, $5.00.

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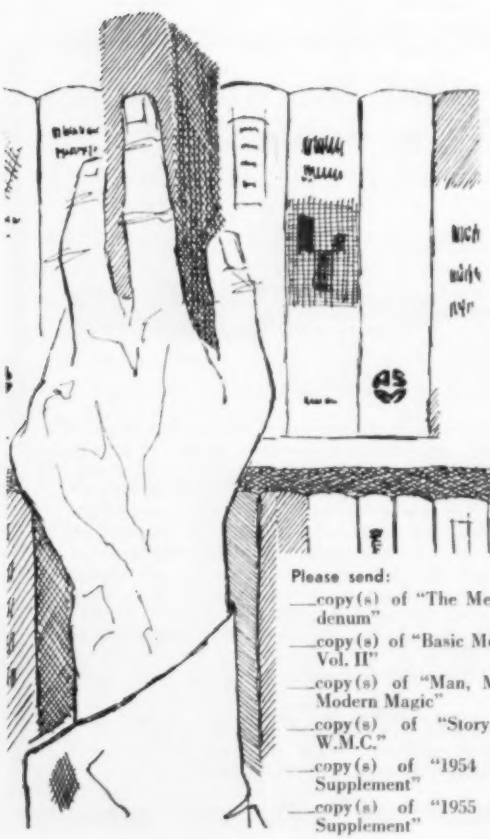

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___copy(s) of "Basic Metallurgy—Vol. II"
___copy(s) of "Man, Metals and Modern Magic"
___copy(s) of "Story of 2nd W.M.C."
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dag® BRAND DISPERSIONS

COLLOIDAL GRAPHITE, MOLY-SULFIDE, VERMICULITE, AND OTHER SOLIDS

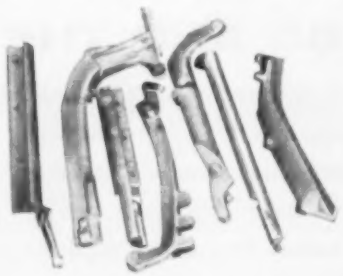
SUPERIOR CASTINGS, LONGER DIE LIFE ATTRIBUTED TO 'DAG' DISPERSIONS

Die casters and molders are expressing a growing preference for Acheson 'dag' brand colloidal dispersions. The consistent high quality of these products and the multiple benefits they offer have obsoleted most other mold cavity coatings. As outlined below, Acheson dispersions greatly aid in the manufacture of more uniformly sound castings having smoother surface finishes, facilitate metal flow and parting, and consequently extend the effective service lives of the dies and molds on which they are used.

Acheson 'Prodag'®, spray-applied on permanent molds at Paragon Aluminum Corporation, has given them consistently higher quality castings and fewer rejects.

Better surface finish with 'Prodag' permanent mold coating is just one of the reasons why Paragon Aluminum Corporation, a Division of Detroit Harvester Company located at Monroe, Michigan, switched to this Acheson product. After four years of experimentation with other mold washes, Paragon chose 'Prodag' — Acheson semi-colloidal graphite in water — and has used it constantly the past seven years. The reasons for its choice are these; uniform consistency, excellent heat-transfer quality, and its hard, smooth, tenacious film which resists flaking and provides easier parting characteristics.

With about 95 per cent of its annual output of more than two million pounds of castings going to the automotive industry, Paragon must insist upon quality. 'Prodag' helps to maintain this standard. These parts for convertible automobile tops are precision-molded from both 355 and 319 aluminum alloy. Molds are preheated before each day's run to 600°F and the casting cycle maintains this temperature. The 'Prodag' dilution ratio is 1 to 4 parts water and is applied to the molds with a commercial spray gun. Aside from occasional touchup at points of greatest wear, this coating lasts through the entire run. Because of the physical contours involved in these comparatively small, light castings, they require rapid cooling in certain areas to insure uniform strength. The 'Prodag' coating — with its proven fast heat transfer ability — allows the castings to cool without breaks or pinholes. And by parting more easily, the high-finish castings which result have given Paragon Aluminum products wide acceptance in this demanding industry.



Typical parts cast at Paragon Aluminum include these automobile convertible top braces. More uniform strength, better finish, and fewer rejects result from this company's use of Acheson 'Prodag'.

If you have a metal casting problem, call in your Acheson Service Engineer. Or if you prefer, write direct for additional information contained in our Bulletin No. 425. Address Dept. MP-128.

'dag' and 'Prodag' are trademarks registered in the U.S. Patent Office by Acheson Industries, Inc.

Colloidal graphite increases die life because of its stability at high temperatures, excellent lubricating qualities, and its ability to prevent adhesion and the scrubbing effect of hot metal. This cannot be said of conventional petroleum compounds which either decompose rapidly at temperatures above 300°F or do not possess the required lubricity necessary under good die casting procedures. It will not volatilize when in contact with the hot metal and cause pock marks due to gas formation. It will perform when present in extremely thin films which will not affect dimensions or cause discoloration of the parts being cast. And since it does not volatilize or otherwise be destroyed in the casting process, it does not need to be applied as often as other lubricants. This fact alone has often increased production as much as 25%. Investigate the use of an Acheson colloidal dispersion in solving your die casting problem . . . *It probably is the very answer you need.*

ACHESON *Colloids Company*

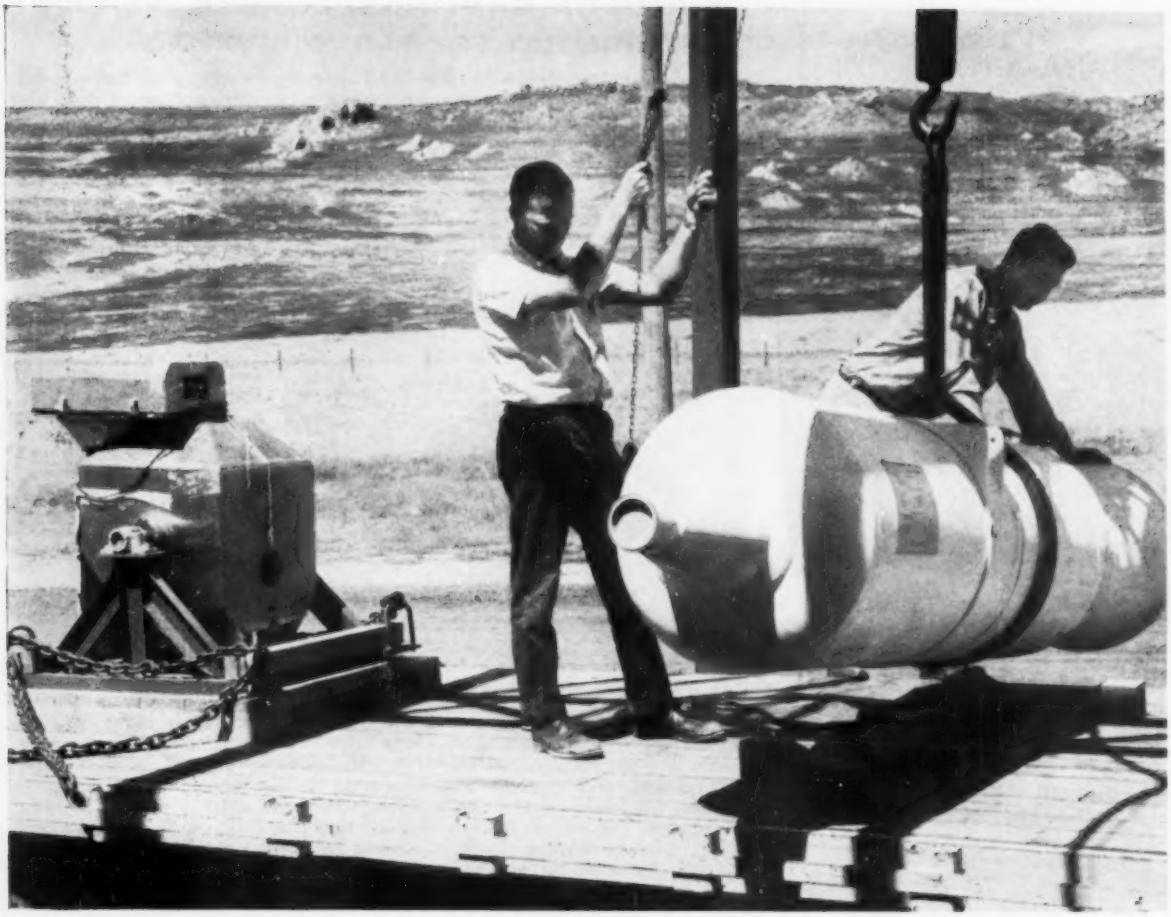
PORT HURON, MICHIGAN

A division of Acheson Industries, Inc.

Also Acheson Industries (Europe) Ltd. and affiliates, London, England

50th ANNIVERSARY 1908 1958

Offices in: Boston • Chicago • Cleveland • Dayton • Detroit • Los Angeles • Milwaukee
New York • Philadelphia • Pittsburgh • Rochester • St. Louis • Toronto



COBALT 60 AND THE MATADOR

Thiokol Chemical Corporation, Utah Division, chose Nuclear Systems' Model 1060 Multitron with a 1,000 curie cobalt 60 source for routine radiography of the Matador engine. The radiographs obtained provide non-destructive testing information which has greatly increased the reliability of the rocket. This unit, along with several others, has been used continuously by Thiokol for the inspection of solid propellants for over a year.

Nuclear Systems offers the most complete line of gamma radiography equipment for this and many other applications.

Call our nearest sales office collect for more information.

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NUCLEAR SYSTEMS

A DIVISION OF THE BUDD COMPANY, Philadelphia 32, Pa.

IN CANADA—TATNALL MEASURING AND NUCLEAR SYSTEMS, LTD.
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Budd

USS "T-1" Steel can be flame-cut, welded, formed, sheared, punched, machined or forged.

How to **beef-up** your equipment without adding fat

Build it stronger, tougher and lighter with USS "T-1" Steel. This remarkable steel was developed especially to meet the needs for bigger tools, stronger equipment, larger yet less massive structures.

USS "T-1" Steel is a low carbon, quenched and tempered constructional alloy steel combining weldability and formability with exceptional strength and toughness. Because of its high yield strength (100,000 psi minimum) you can cut weight safely—in actual applications, as much as 25% to 50% weight reductions have been achieved.

Total costs can frequently be reduced, too. In applications such as heavy machinery, rotating parts, pressure vessels and bridge members, steel costs can be lowered by reduction in cross section and substantial savings experienced in welding, maintenance, freight and erection costs.

Also, in equipment subjected to impact abrasion, USS "T-1" Steel pays off. Users report service life increases ranging from 25% to 100%—or more. Power shovel buckets, bulldozer blades, coal and ore bins . . . all cost less in the end when made of "T-1" Steel because they last longer, cost less to maintain.

Write for free book. The many advantages, applications and cost-saving features of this versatile steel are completely described in our book USS "T-1." United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

USS and "T-1" are registered trademarks

United States Steel Corporation – Pittsburgh
Columbia-Geneva Steel – San Francisco
Tennessee Coal & Iron – Fairfield, Alabama
United States Steel Supply – Steel Service Centers
United States Steel Export Company

USS **United States Steel**

Why cyclotron magnet frames are made from forgings

Man is in a desperate race to learn more about magnetics. One famous acres-big cyclotron could be reduced to the size of a steamer trunk if they could only find a way to increase the magnetic field strength by 20 times. And already we see evidence that very strong magnetic fields may hold the secret to one of man's most sought-after dreams: sustained nuclear fusion power generation.

But when you double the strength of a magnetic field, the energy density or pressure increases *fourfold*. A not-uncommon 50,000 gauss magnetic field exerts a pressure of about 1,400 psi; but other laboratory experiments have already created fields of 1½ million gauss for a few microseconds, and they confidently expect to hit *10 million* gauss before long!

To contain the fantastic forces, designers of very large electromagnets turn to high-quality forged steel parts, and they very often come to United States Steel to ask for USS Quality Forgings.

The picture shows a cyclotron electromagnet frame that will go into service at Oak Ridge National Laboratory, Oak Ridge, Tennessee. It is made from six USS Quality Forgings that total 193 tons including the two cylindrical pole pieces. The pole pieces are machined to a .005″ flatness, and are parallel to within .005″. These tolerances are essential for close control over the bombarding particle beam—which often operates at velocities which approach 50,000 miles *per second*. All six forgings were melted, forged, machined, heat-treated and inspected right at our Homestead Forgings Division, and we also furnished all dowels (4½″ in diameter), nuts, bolts and lifting eyes.

Many cyclotron and nuclear reactor parts are made from USS Quality Forgings because buyers have learned that they are made from the finest steel, on the most modern equipment, by the most skilled forging men in all the world. No matter what kind or size of USS Quality Forgings you buy, you get the advantage of these same facilities. Please address inquiries or requests for our free forgings booklet to United States Steel, 525 William Penn Place, Pittsburgh 30, Pa.

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USS United States Steel

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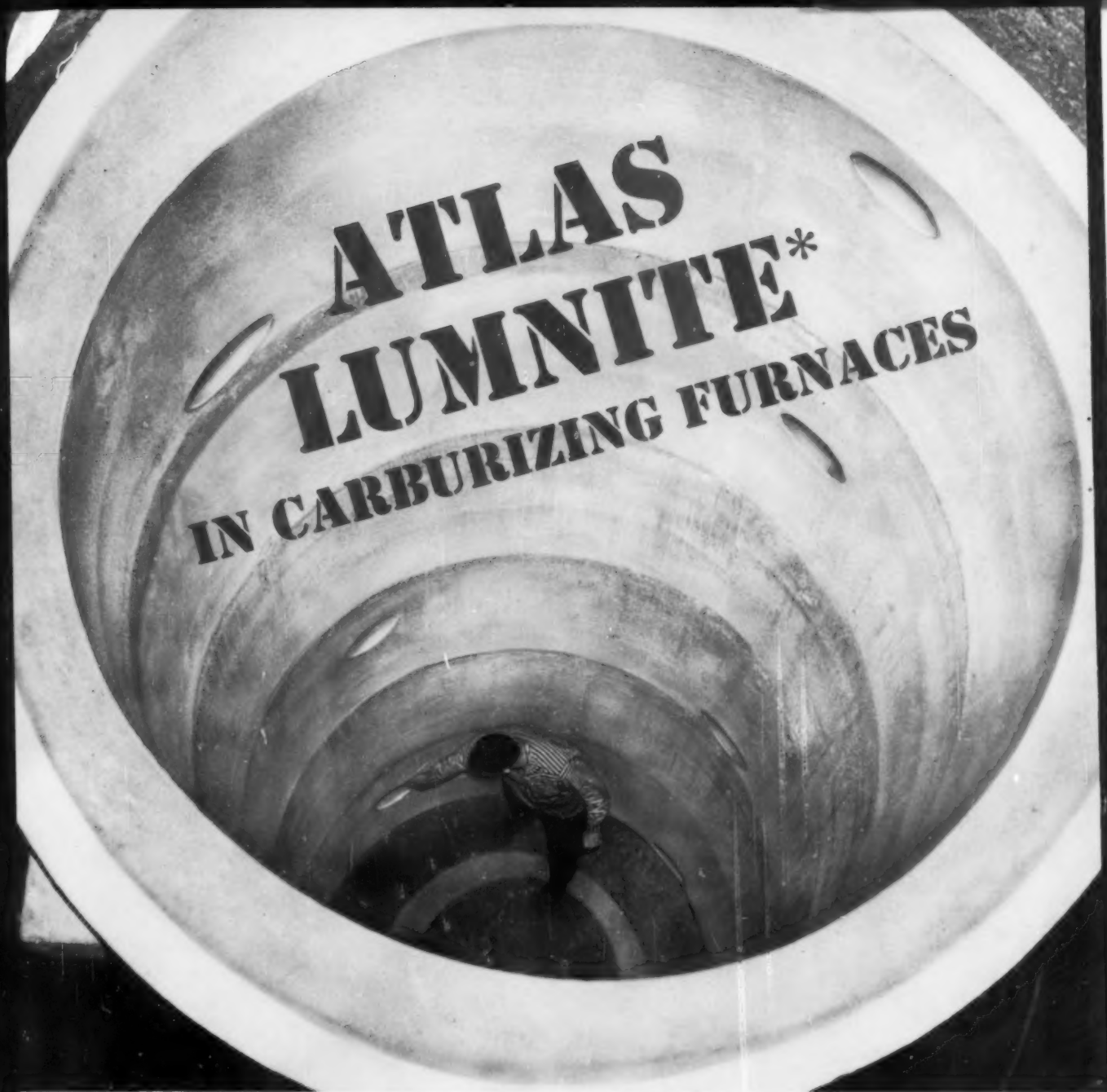

Vertical pit-type carburizing furnace (9' x 24') lined with an insulating castable refractory made with LUMNITE cement. Operating temperature to 1800° F. Badall Engineering & Manufacturing Co., Hammond, Ind. Castable used: "Kast-O-Lite," product of A. P. Green Fire Brick Co., Mexico, Mo.

"...withstands thermal shock...reduces heat loss,"

says Fred F. Badalli, Badall Engineering & Manufacturing Co.

- Refractory concrete linings (made with LUMNITE calcium-aluminate cement and selected aggregates) resist furnace temperatures to 2600° F . . . protect against thermal shock due to heating-cooling cycles . . . provide insulation.
- Construction is fast, easy, economical. Linings can be cast in place, troweled or "gunited" . . . service strength is reached in 24 hours.

For maximum convenience, use castables made with LUMNITE cement. These are packaged mixtures, ready for use. Just add water, mix and place. Made and distributed by leading manufacturers of refractories.

For literature on refractory concrete, write:
Universal Atlas, 100 Park Avenue, New York 17, N. Y.

"LUMNITE" is the registered trade-mark of the calcium-aluminate cement manufactured by Universal Atlas

UNIVERSAL ATLAS CEMENTS

Universal Atlas Cement
Division of United States Steel

USS
TRADE MARK

L-166

OFFICES: *Albany · Birmingham · Boston · Chicago · Dayton · Kansas City · Milwaukee · Minneapolis · New York · Philadelphia · Pittsburgh · St. Louis · Waco*

Specification

3-G-170

Trade names you can trust!

HOSKINS

Chromel-Alumel

THERMOCOUPLE ALLOYS

Specification

3-G-178

Available guaranteed to special close tolerances for precision laboratory and research work

Hoskins standard grade Chromel-Alumel thermocouple alloys for industrial heat treating applications are unconditionally guaranteed to register true temperature – e.m.f. values within ±4° F. from 32° to 530° F., and within ±¾% at temperatures from 531° up to 2300° F. For precision laboratory and research work, however, Chromel-Alumel is available under specification #3-G-170 in suitable selected wire sizes guaranteed to the special close tolerances shown in the table at right. Or, under specification #3-G-178, they are also offered in sizes from 2 through 40 gauge guaranteed to one-half the standard grade tolerance in the range from 1050° F. to maximum recommended operating temperatures.

CHROMEL-ALUMEL — SPECIFICATION #3-G-170

Wire Size	Temp. Range	Tolerance
18, 20, 22 gauge	1000°–2000° F.	±5° F.
24 and 28 gauge	1000°–1600° F.	±5° F.
30 thru 40 gauge	1000°–1400° F.	±5° F.

Ask for them by name! Your instrument manufacturer or pyrometer service company can supply your needs for bare or insulated wire and assembled couples – plus Chromel-Alumel *extension lead wire* to eliminate "cold-end" errors. Wires are available, too, direct from factory stocks – so ask for them by name. "Chromel-Alumel" thermocouple wire – *trade names you can trust!*

Chromel-Alumel thermocouple alloys are produced exclusively by

HOSKINS MANUFACTURING CO.

4445 LAWTON AVE. • DETROIT 8, MICHIGAN • PHONE TYler 5-2860

1908 1958

Joseph Smilnak views a radiograph made with Du Pont Film

"The consistent quality of Du Pont X-Ray Film

gives us faster, more efficient inspection"

states Joseph A. Smilnak, Industrial X-ray Engineer, Smith X-ray and Research Company, Ferndale, Michigan

Du Pont Type 506 and Type 510 Industrial X-ray Films have the necessary speed, latitude and fine detail to permit the "sandwich" technique for inspection of complex parts for military use, Mr. Smilnak tells us.

"We use this technique when we inspect parts that have both thick and thin sections in the same area," he says. "With Du Pont 506 and 510, a fast and slow film respectively, quality is so consistent that we can radiograph the complete area in a single exposure. With both films together in one holder, the thick sections record accurately on the 506 film . . . the thin on the 510.

"If films of this quality were not available," Mr. Smilnak continues, "inspection of these parts would take twice the time, with two separate exposures—not counting the added processing and handling time.

"So you see why we use Du Pont film. It makes possible two real benefits—speed and efficiency."

* * *

If you'd like to get these benefits for yourself and you require film of the finest, most consistent quality, order Du Pont X-ray Film. For more information and technical data, write Du Pont Photo Products Department, 2432-A Nemours Bui'ding, Wilmington 98, Delaware. In Canada: Du Pont Company of Canada (1956) Limited, Toronto.

DU PONT

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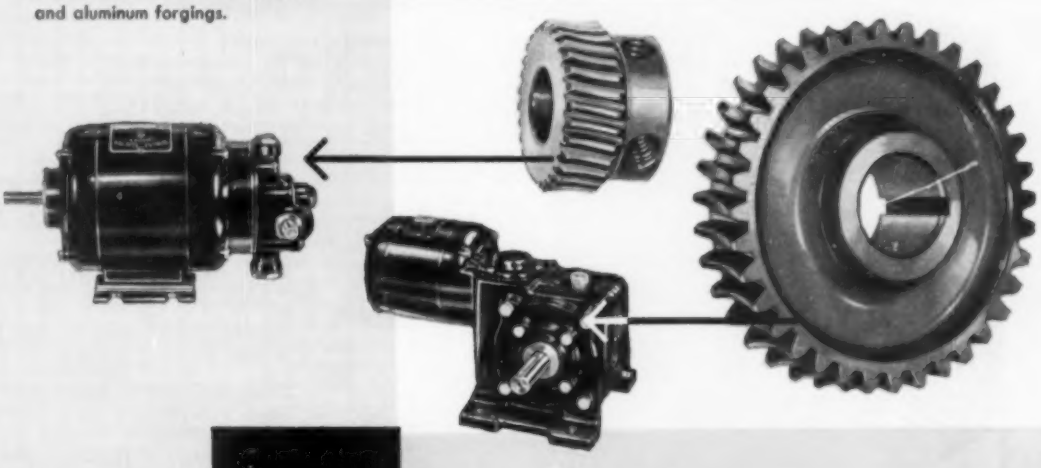
Better Things for Better Living . . . *through Chemistry*

MUELLER BRASS CO. forged gears improve dependability and performance of BODINE electric motors

For combined high shear strength and maximum wear life in their single and double reduction speed reducer motors, Bodine Electric Company of Chicago uses gears forged from Mueller Brass Co. 603 Alloy.

Bodine has specified Mueller Brass Co. forged gear blanks because of their consistently high quality . . . there is no porosity, foreign inclusions or defects typical of cast blanks. The hot working of the metal followed by heat treatment to the desired physical properties produces a refined grain structure to give uniform machining and wear in service. The forged blanks are consistent in size and held to close tolerances. Bodine has also found that the excellent machinability of the blanks in the hobbing operation increases overall hob life.

For forgings of high tensile strength, high density, minimum porosity, light weight, corrosion resistance, good machinability and low costs with little scrap loss, it pays to specify forgings from the Mueller Brass Co., the world's largest producer of brass, bronze and aluminum forgings.



only the man from Mueller Brass Co.

can offer unbiased advice on the "one best way" of producing your parts, because Mueller Brass Co. is the *only* fabricator in the country offering all these methods of production . . . assuring you the best product at the best price . . . made the one best way.

Write today for complete catalogs on any of these products.

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PLASTICS INJECTION MOLDING

COLD-PREST IMPACT EXTRUSIONS

SCREW MACHINE PRODUCTS

POWDER METAL PARTS

RED BRASS CASTINGS

Also producers of: Super Cutting Red Tip Brass Rod • Aluminum Extrusions Aluminum Sheet, Coil and Strip • Plastic Pipe and Fittings • Copper Tube and Solder Type Fittings •

MUELLER BRASS CO. PORT HURON 28, MICHIGAN

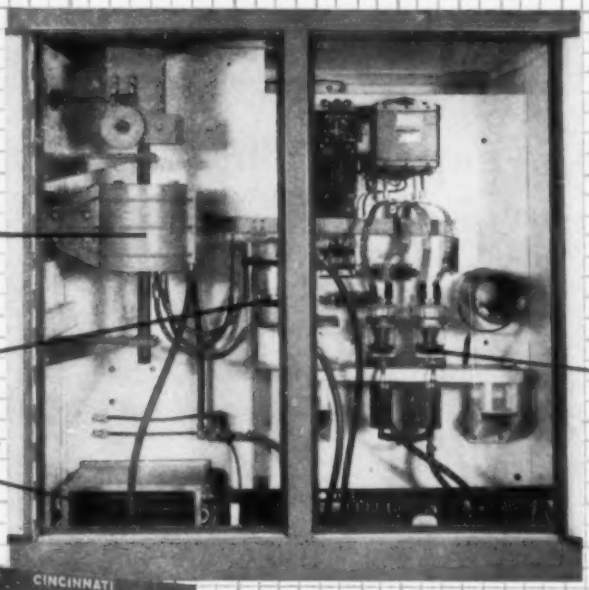
262

A dividing wall separates the oscillator section (shown at right), from the power supply section (shown below). Door interlock switches are used on all access panels. All components are readily accessible and arranged for easy maintenance.

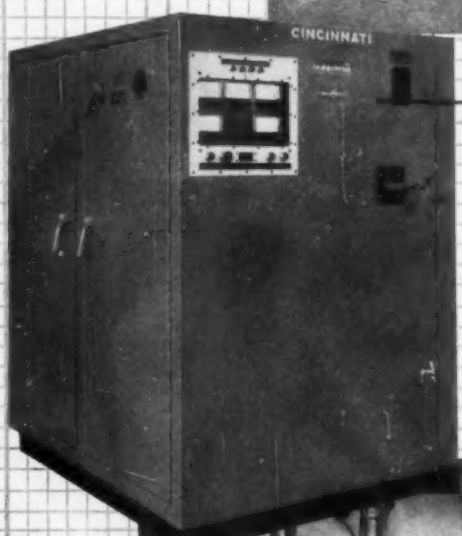
With this variable output RF transformer, output can be varied under load from 30% to 100% rating by positioning one dial.

Simplified, high KVA rated tank circuit includes vacuum capacitors for lowest possible power loss.

Cabinet air is cooled by water heat exchanger and blower. Air and water temperatures are thermostat controlled.



New type, extra-rugged duty low Mu oscillator tubes are especially designed for rugged industrial use. Filament supply to these tubes are both voltage regulated at ± 1% of nominal and ± 3% over a 27% line supply variation, and current limited to 200% inrush. Rectifier filaments also receive the same regulated supply. This insures longest tube life.

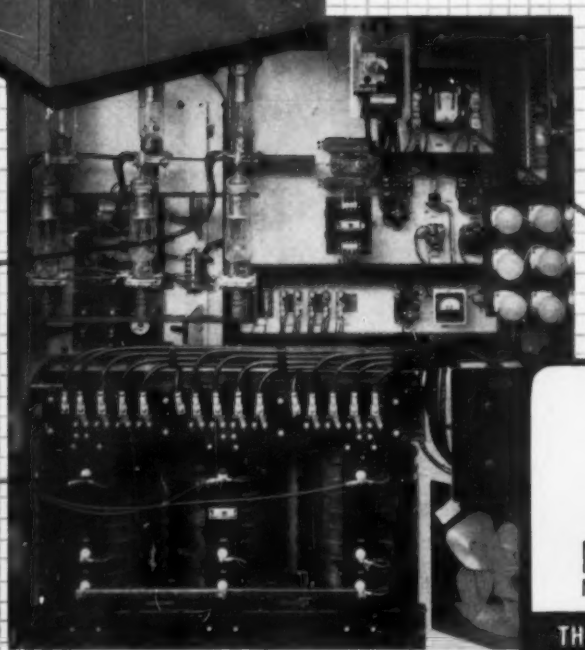


Here is the 30KW Cincinnati Inductron - operates at frequencies of approx. 1200KC. Also built in 15KW and 50KW capacities. A compact, self-contained, one cabinet unit.

Important Note to Users of Induction Heating Equipment

The CINCINNATI INDUCTRON has the design that provides for highest operating efficiency - maximum component life - easiest, lowest-cost maintenance. Check these features-

All controls are panel mounted, providing easy access for inspection and maintenance. Controls provide a more complete cross-section indication of the operation of the circuit than any other induction heater in the field.



Three phase, full wave bridge rectifier circuit uses industrial-type, heavy duty mercury vapor rectifier tubes. Tubes are arranged for even, forced air cooling.

Complete encapsulation against moisture and dirt, plus pie-type secondary windings, and even, forced air cooling, insure long life for the plate supply transformer.

For detailed information, call in a Meta-Dynamics Division field engineer.

inductron
flamatic
hardening machines

META-DYNAMICS DIVISION
Machines for Metal Forming and Heat Treating

THE CINCINNATI MILLING MACHINE CO.
Cincinnati 9, Ohio, U.S.A.

CINCINNATI

APPLICATION and EQUIPMENT new literature

1211. Alloy Steel
208-page book gives more than 50 complete case histories of alloy steel usage. *Climax Molybdenum Div.*

1212. Alloy Steel
40-page book on applications of heat treated, special alloy steel. *Jones & Laughlin*

1213. Alloy Steel
68-page "Aircraft Steels" includes revised military specifications. Also stock list. *Ryerson*

1214. Alloy Steels
New 20-page booklet describes three high-strength, low-alloy steels. Mechanical characteristics and applications of each. *Kaiser Steel Corp.*

1215. Alloy Tubing
New data book on small precision alloy tubing. It covers drawing, annealing, finishing and testing. Properties, applications. *Precision Tube Co.*

1216. Aluminum Alloys
File on high-strength aluminum alloys gives advantages, applications, properties. *Frontier Bronze Corp.*

1217. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

1218. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions*

1219. Aluminum Extrusions
Catalog of extrusion dies in stock. *Jarl Extrusions*

1220. Ammonia
6 and 4-page bulletins on ammonia storage units and nitrogen generator. *Hamler Industries, Inc.*

1221. Ammonia
New 69-page data book on anhydrous ammonia and ammonia liquor. Chemical and physical properties, specifications, analytical procedures, bibliography. *Nitrogen Div.*

1222. Ammonia Dissociators
Data on Drever ammonia dissociators. Also nitriding, tempering, carburizing, and salt bath units. *W. H. Kay Co.*

1223. Atmospheres
Bulletin on liquid metal systems inert gas purifiers, and furnaces with ultra high purity inert atmospheres. *Liquid Metals, Inc.*

1224. Austempering
Bulletin No. 167 on mechanized salt bath installation for continuous heat treatment of farm tools. *Ajax Electric*

1225. Barrel Cleaning
Data sheet on Model RD/2 barrel machine for deburring, descaling, burnishing, polishing. Size and capacity. *Casalbi*

1226. Bimetal Applications
44-page booklet, "Successful Applications of Thermostatic Bimetal", contains uses, formulas, calculations. *W. M. Chace*

1227. Blast Cleaning
Complete information on Malleabrasive for cleaning and finishing. *Globe Steel Abrasive*

1228. Boron Stainless
8-page booklet on composition, structure, corrosion resistance, welding and mechanical properties of 1% boron stainless steel. *Superior Steel*

1229. Brass Wire
10-page booklet gives properties, finishes, chemistry of extruded cold heading brass and copper wire. *Chase*

1230. Burner
New Bulletin 109 on combination gas and oil burners. Description and output data. *Thermal Research & Engineering*

1231. Burners
Buzzer Catalog No. 1570 describes industrial gas burners, furnaces and accessories for heat treating, metal melting, soldering and drying. *Charles A. Hones*

1232. Calibration
New Bulletin 169 on calibrating and weighing system. Advantages, construction, operation, specifications. *Morehouse Machine*

1233. Carbon Brick
Bulletin on properties, grades, applications of carbon and graphite brick for handling corrosive chemicals and molten metals. *National Carbon*

1234. Carbon Monoxide Analyzers
New brochures on carbon monoxide analyzers and self-contained combustible gas alarm. Applications. *Mine Safety Appliances*

1235. Carbonitriding
Bulletin 241 on gas-fired radiant-tube furnace for carbonitriding and other heat treating. *Lindberg Engineering*

1236. Castings
12-page bulletin on ArmaSteel castings. Properties, applications, machinability and heat treating. *Central Foundry Div.*

1237. Ceramics
4-page bulletin D2-56 on physical properties of 10 industrial ceramics. Fabrication methods and important service features. *McDanel Refractory Porcelain*

1238. Chemicals
22-page bulletin on industrial chemicals lists those available and illustrates their manufacture and testing. *Harshaw Scientific*

1239. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

1240. Chromium Plating
4-page bulletin on new "crack-free" chromium plating process. *Metal & Thermit*

1241. Cleaning Compound
Bulletin B-6 on water displacing compound for producing unspotted, dry surfaces. *Apothecaries Hall*

1242. Coated Metals
Bulletin on roll coating shows how it is done and includes samples. *Roll Coater*

1243. Coating
New 12-page booklet 258 on Kanigen, chemically deposited nickel alloy coating. Heat treating curves, corrosion studies. *General American Transportation*

1244. Coatings
Bulletin gives uses of various conversion coatings for zinc and cadmium. *Chemical Corp.*

1245. Coatings
New 8-page engineering data Bulletin 136A on wire and powder sprayed coatings of metals. Basic characteristics. Mechanical and electrical-electronic applications. *Metallizing Engineering Co.*

1246. Compressors
New 12-page Bulletin 126-B on application of turbo compressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

1247. Copper Alloys
24-page manual on alloys in rod form. Typical parts. Specifications covering alloys described. *Mueller Brass*

1248. Corrosion-Proof Equipment
Bulletins on corrosion-proof tanks, ventilating equipment, agitators, baskets. *Heil Process Equipment*

1249. Corrosion Resistance
20-page bulletin on copper alloys for corrosion resistance. Table gives use with 150 media. *Ampco*

1250. Cutting Oil
New folder describing nine types of cutting oils for varied applications. *Gulf Oil*

1251. Cutting Tools
36-page booklet analyzes and compares carbon, high speed, cast alloy and carbide tool materials. *Allegheny Ludlum*

1252. Degreasers
Folder on vapor and solvent degreasers describes equipment and advantages. *Randall Mfg.*

1253. Drawing Dies
12-page bulletin on turks head, adjustable draw die. Basic types, development of turks head. *Fenn Mfg.*

1254. Dryer
New Bulletin 130 describes aero aftercooler for removing moisture from compressed air and gas. Application of equipment. *Niagara Blower Co.*

1255. Ductile Vanadium
New brochure on high purity vanadium metal. Properties, applications. *Vanadium Corp.*

1256. Electric Furnace
New Bulletin 5711B on conveyor heat treating furnace. Design specifications, components and control equipment. Heat control curves. *C. I. Hayes*

1257. Electric Furnaces
Catalog on electric furnaces and ovens for hardening, tempering, annealing, drawing, drying, baking, enameling. *Cooley Electric Mfg.*

1258. Electric Furnaces
Data sheet describes and gives specifications of standard nonmetallic resistor furnaces. *Harrop Electric Furnace Div.*

1259. Electric Furnaces
Bulletin on electric heat treating fur-

Introducing Allied's

IRILAC™ #1000

New Clear Protective Coating for All Metals . . . as safe and easy to handle as Water!

New method of protection incorporates corrosion inhibitors in a water-soluble polymer base. Dries to an extremely thin, tough, durable coating—clear in color. Does not chemically affect base metal or any post-treatments. Used as a protective treatment alone or to enhance value of post-treatments.

Allied's new Irilac #1000 is a concentrated solution of a water-soluble polymer with built-in complex corrosion inhibiting materials. It was developed to answer the needs of the metalworking industry for a non-conversion process that will provide corrosion resistance and resistance to fingerprinting and abrasion on base metals and electrochemically or chemically finished surfaces—without changing the appearance of the metallic surface.

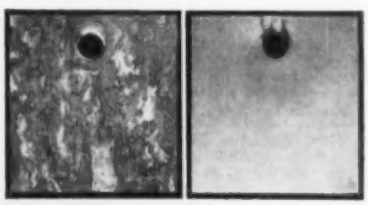
There are no hazards involved—Irilac is non-fuming, non-toxic, and requires no special fire prevention measures.

THE PROCESS

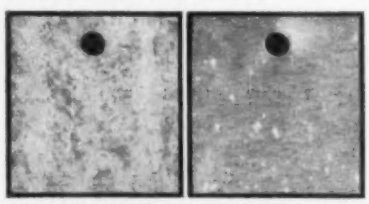
Irilac #1000 is diluted with water to provide a simple one-pass working solution. It is then applied by dip, brush or spray and forms a coating that quickly *bonds* to the metal surface without reacting with the surface.

THE PROPERTIES

The resulting coating is clear, transparent, thin yet durable. It has excellent water-resistant properties, and can be rubbed, handled and subjected to rough treatment. The surface to which Irilac has been applied is not altered—in fact, the transparent coating brings full tone to colored surfaces and clarity to iridescent surfaces. The water-thin physical characteristic of the solution means that the coating provides protection in recessed areas that are difficult, if not impossible, to protect with other methods.



STEEL PANELS: bare (left) and coated with Irilac (right) after 8-hour salt spray.



ALUMINUM PANELS: bare (left) and coated with Irilac (right) after 168-hour salt spray.

WHERE IRILAC CAN BE USED

Irilac #1000 can be applied to *any* metal—wet or dry—treated or untreated. All metals can be processed in *one* operation in the same solution. It can be applied in conjunction with any process—over Iridite, anodized, phosphated surfaces, black oxide, etc. Surfaces treated with Irilac provide a good base for paint.

APPLICATION ADVANTAGES

No other process or material available for the protection of metals offers all the application advantages found in new Irilac #1000:

1. It can be applied to any clean metal simply by dip, brush or spray. No special equipment is required.
2. Saves time—just apply and dry—no reaction time required.
3. No hazards involved—no exhaust or special fire protection equipment is required. Irilac is non-fuming and non-toxic.
4. Saves space. Presents no disposal problem. Low in first and final costs.

Because of its versatility and complete safety, Irilac has unlimited uses. For example, it will protect aluminum furniture, brass hardware and fixtures, steel parts of all types, zinc castings, etc. In fact, any base metal or plated surface, or those treated with electrolytic or chemical post-treatments, can be improved or enhanced with Irilac.

IRILAC #1000 MAY BE THE ANSWER TO YOUR PROTECTION PROBLEM

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naces gives summary of progress in furnace developments. *Holcroft*

1260. Electric Furnaces
8-page Bulletin 570 on heat treating, melting, metallurgical tube, research and sintering furnaces. Custom designs for special requirements. *Pereny*

1261. Electrodes
New 12-page Bulletin No. MW-222 on hard surfacing electrodes and wire. Checklist of uses with various types of welding equipment. *A. O. Smith Corp.*

1262. Electron Microscopy
4-page bulletin on specimen preparation for electron microscopy. *RCA*

1263. Environmental Chambers
New 28-page booklet on testing chamber simulating atmospheric conditions. Charts, technical data, applications. *Webber Mfg. Co., Inc.*

1264. Finishing
New 20-page booklet on tumbling media for barrel finishing. Types of abrasive, applications, sizes and functions of barrels. Job analysis. *Electro Minerals Div., Carborundum*

1265. Flow Meters
Bulletin 203 on flow meters for gas used in heat treating. *Waukee Eng'g.*

1266. Forging Materials
New 16-page booklet describes forging materials for aircraft and missile structural parts. 11 charts compare physical properties. *Steel Improvement & Forge*

1267. Forgings
Two bulletins on upset forging process, advantages of upset forging, quotation specifications. *Champion Rivet*

1268. Forgings
Folder on facilities for production of flat-die forged products. Electronic equipment used. *Smith-Armstrong*

1269. Formed Shapes
26-page catalog No. 1555 contains drawings and dimensions of more than 100 shapes. *Roll Formed Products Co.*

1270. Freezer
Data on chest for use down to −95° F. for production and testing. *Revco*

1271. Furnace
6-page Bulletin No. 805 on laboratory vacuum furnace. Specifications, applications, accessories. *Kinney Mfg.*

1272. Furnace
4-page bulletin KM-570 on Karbo-Matic automatic furnace for hardening, carbonitriding or carburizing. Operation. Heating elements. *Pacific Scientific*

1273. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

1274. Furnace Fixtures
Bulletin 111 on cast Ni-Cr fixtures for gas carburizing. *Fahralloy*

1275. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood*

1276. Furnaces
6-page folder on gas-fired, oil-fired and electric furnaces. Typical installations. *Electric Furnace Co.*

1277. Furnaces
New Bulletin 357 on conveyor and pusher furnaces for continuous produc-

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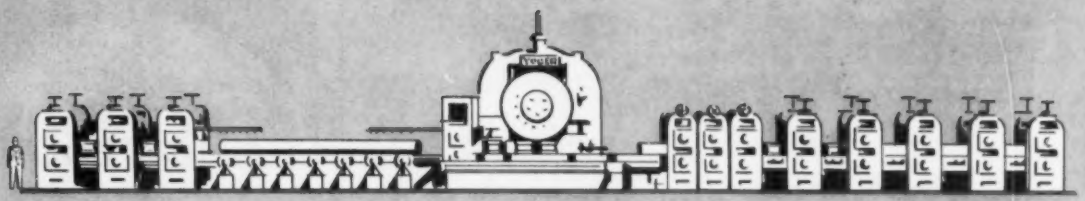

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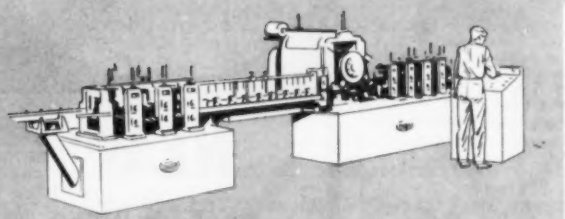

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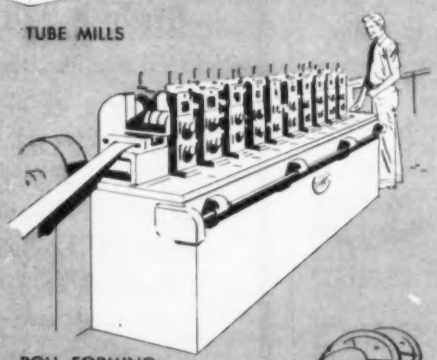

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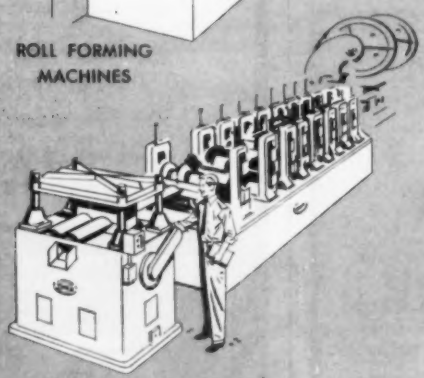

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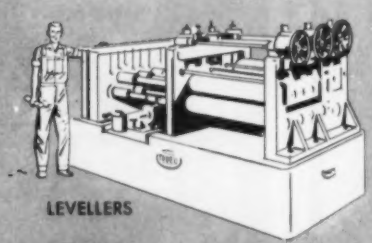

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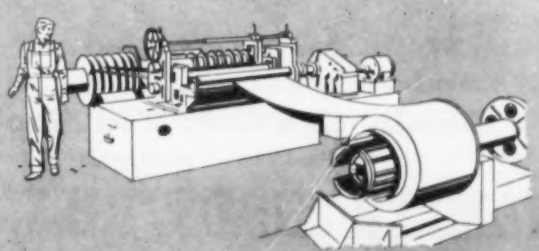

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tion with precise control. Temperature ranges from 400 to 2600° F. *Hevi Duty Electric*

1278. Furnaces
New 8-page Bulletin 70 on metal melting and heating equipment. Design, melting performance table. *Inductotherm*

1279. Furnaces
New brochure describing heating, treating, processing and laboratory furnaces. *L & L Mfg. Co.*

1280. Furnaces
Data on line of melting, heating and heat treating furnaces for ferrous and nonferrous metals. *Loftus Engineering*

1281. Furnaces
New 12-page catalog on electric heat treating furnaces. Data on each of 57 models. Controls, instruments, elements and accessories. *Lucifer Furnaces, Inc.*

1282. Furnaces
Lists of surplus furnaces for sale. *Joe Martin Co.*

1283. Furnaces
New 8-page Folder SC-175 describing wide range of industrial furnaces. *Surface Combustion*

1284. Furnaces
New Bulletin 200 describes complete setup for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

1285. Gold Plating
8-page paper gives bath composition, equipment and operating conditions, and metallurgical characteristics of 24K gold plate on various base metals. *Sel-Rex*

1286. Graphite
20-page brochure on significance of graphite as electrodes, anodes, molds, and specialties in electrometallurgy and electrochemistry. *Great Lakes Carbon*

1287. Graphite
4-page catalog section S-5050 on impervious graphite and resin-base cements for corrosive service. 2-page table gives recommendations for commercial applications. *National Carbon*

1288. Graphite
Folder on graphite crucibles, funnels, and special preformed electrodes. High-purity powder. *United Carbon Products*

1289. Gripping Fixtures
New bulletin on line of gripping fixtures for use in tension, compression, transverse or shear to test any material. *W. C. Dillon*

1290. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

1291. Hardness Tester
Bulletin A-16 on micro-reflex hardness testers. Loads to 3000 gr. Zeiss optical system. *Gries Industries, Inc.*

1292. Hardness Tester
Bulletin on Brinell tester with test head for deep and offset testing. *King Tester*

1293. Hardness Tester
4-page bulletin on air-operated Brinell metal hardness tester. Operating principles, specifications. *Tinius Olsen*

1294. Hardness Tester
Catalog 505 on Frank hardness tester for Rockwell B and C, Brinell and Vickers hardness tests. *Opto-Metric Tools*

1295. Hardness Tester
Data on hardness testing scleroscope with equivalent Brinell and Rockwell C numbers. *Shore Instrument*

1296. Hardness Testers
Folder on portable hardness testers for testing of various sizes, shapes and types of metal. *Newage Industries*

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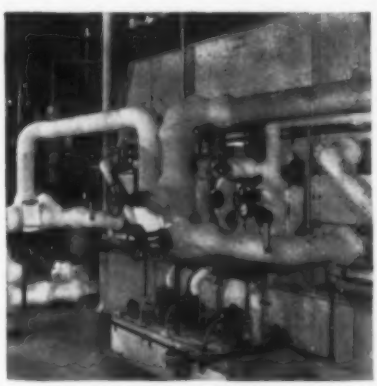
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This design calls for a high temperature alloy bar to be bent and flash-welded into a ring. When it is machined to cross section, as much as 40% of the metal is machined away.

In a part like this, you really end up with nothing more than the core of the bar with which you start . . . which was once the core of an ingot.

That is why, in almost every case, poor service or high reject rates in parts like this can be traced to inconsistency in the ingot. You get a good part *only* when the steel ingot itself is consistent through the core all along the centerline. That's what MEL-TROL gives you.

MEL-TROL achieves greater uniformity in ingots than any other known system of steelmaking today. It is a process combining an exclusive, patented ingot mold design with an integrated system of quality controls. The result is the most complete freedom from variation in toughness and strength between surface material and the ingot core ever attained in commercially available high temperature alloys.

Mechanical properties at both room and elevated temperatures are also more consistent than in conventionally made alloys. When you specify MEL-TROL alloys, you're specifying—and insuring—the best performance you can put into high temperature parts. The Carpenter Steel Company, 133 W. Bern Street, Reading, Pa.

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Alloy Tube Division, Union, N. J.
Webb Wire Division, New Brunswick, N. J.
Carpenter Steel of New England, Inc., Bridgeport, Conn.

1297. Hardness Testers
20-page Catalog DH-325 on normal hardness testing. Applications, advantages, accessories. *Wilson Mechanical Instrument Div.*

1298. Heat Treat Pots
Catalog on pressed steel pots for lead, salt, cyanide, oil tempering and metal melting. *Eclipse Industrial Combustion*

1299. Heat Treat Pots
6-page folder gives stock shapes and sizes. Tips on installation and use. *Electro-Alloys Div.*

1300. Heat Treating
Heat Treat Review, Vol. 9, No. 2, contains article on "walking beam" furnace and discussion of modern brazing equipment. *Surface Combustion*

1301. Heat Treating
Monthly bulletin on used heat treating and plating equipment available for immediate delivery. *Metal Treating Equipment Exchange*

1302. Heat Treating Equipment
New bulletin on formed and welded alloy heat treating furnace fabrications. *Alloy Engineering Co.*

1303. Heat Treating Equipment
New brochure on complete line of heat treat baskets and custom designed heat treat fixtures. *Bix Co.*

1304. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

1305. Heat Treating Fixtures
32-page Catalog G-10A lists process equipment, heavy welded fabrications, muffles, trays, fixtures for furnaces, heat treating equipment, pickling equipment. *Rolock*

1306. Heat Treating Fixtures
New 16-page Catalog M-7 on heat treating and corrosion resistant alloy fabrications. *Wiretex Mfg. Co.*

1307. Heat Treating Furnaces
Folder on industrial furnaces. Continuous designs. Insulation. *Pacific Industrial*

1308. Heat Treating Supplies
Data sheets on carburizing, hardening, tempering, nitriding salts, metal cleaning and rust prevention materials. *Heatbath*

1309. Heat Treatment
Bulletin 200 on car hearth, rotary hearth, pit, roller hearth, belt, chain, pusher, and "hi-head" furnaces. *R-S Furnace*

1310. Heaters
New 52-page Booklet GEC-1005I on electric heaters and heating devices. Specifications, processes, applications. *General Electric Co.*

1311. Heaters
Bulletin on immersion heaters for electroplating solutions. *Glo-Quartz*

1312. Heaters
New Bulletin L-1244 on Chromalox stud heaters. How to use and table of sizes, ratings and prices. *Edwin L. Wiegand Co.*

1313. High-Alloy Castings
16-page bulletin, No. 3354-G, gives engineering data concerning castings used for resisting high temperatures, corrosion and abrasion. *Duraloy Co.*

1314. High-Purity Metals
12-page booklet on the ultra-pure indium, tin, zinc, lead, cadmium, bismuth and silver metals. Special research grades of indium and antimony. *Consolidated Mining & Smelting Co.*

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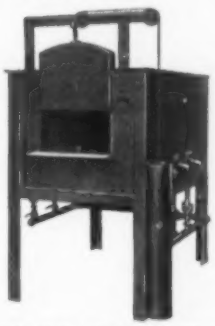

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We have successfully applied this method to heating aluminum billets to forging temperatures with both startling and profitable results. It can be applied just as profitably to other types and forms of ferrous and nonferrous metals.

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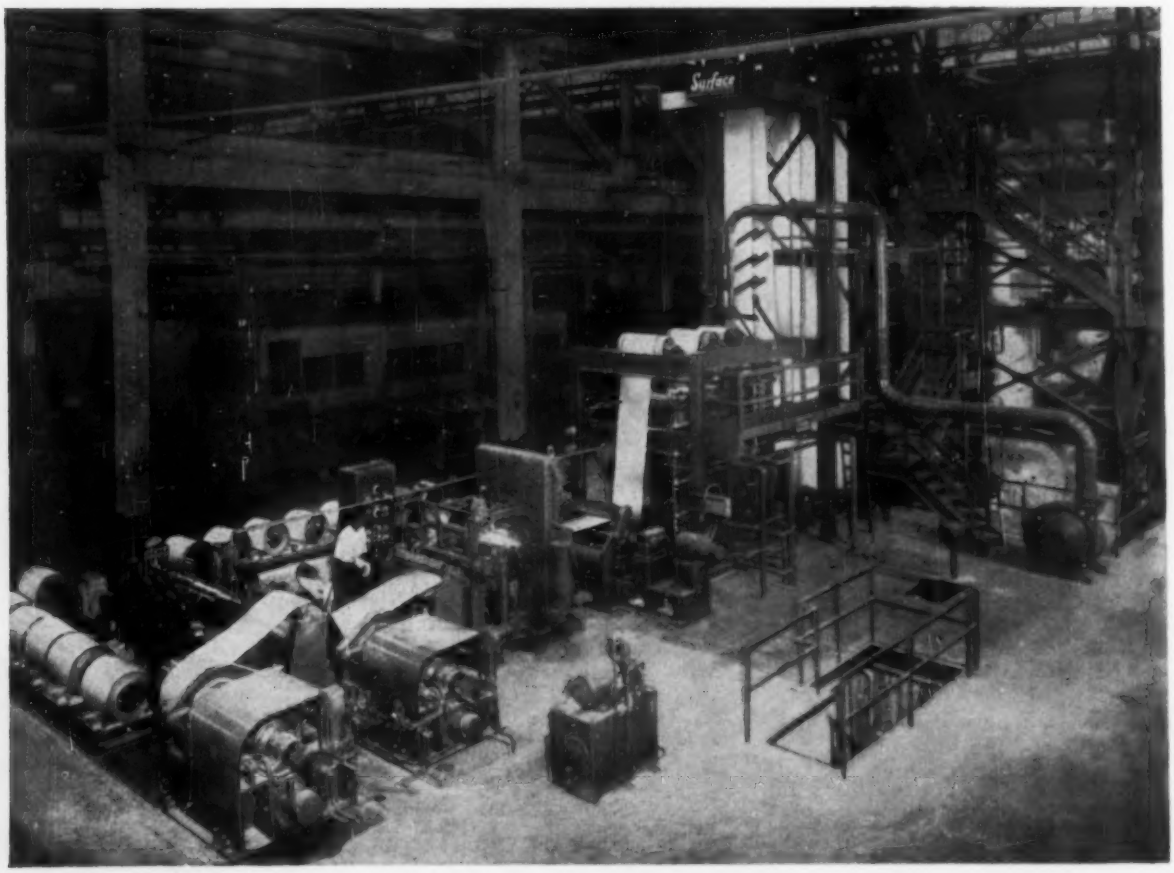
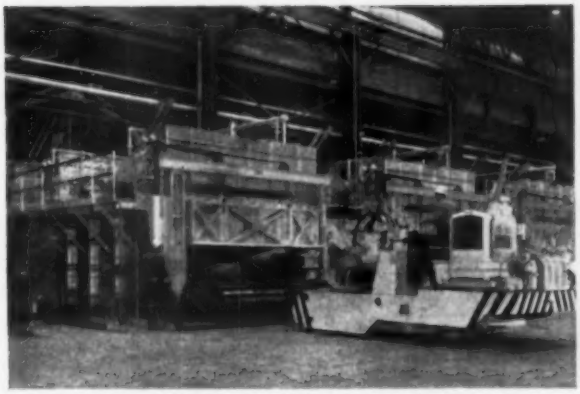
Surface Combustion Corporation, 2377 Dorr Street, Toledo 1, Ohio. In Canada: Surface Industrial Furnaces, Ltd., Toronto, Ontario.

heat nonferrous metals faster...

Incredible speeds have been achieved in this new continuous brass strip heating installation by Surface.





A big aluminum billet is removed from one of a battery of Surface furnaces which heat 7000 lbs/hr each for forging.

Thousands of 14S aluminum parts a day are solution heat treated and aged in this Surface continuous furnace line.

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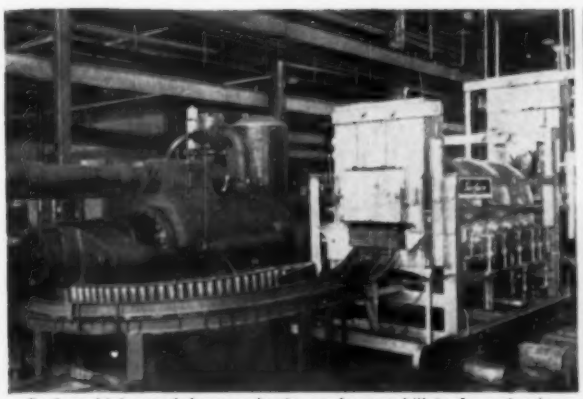
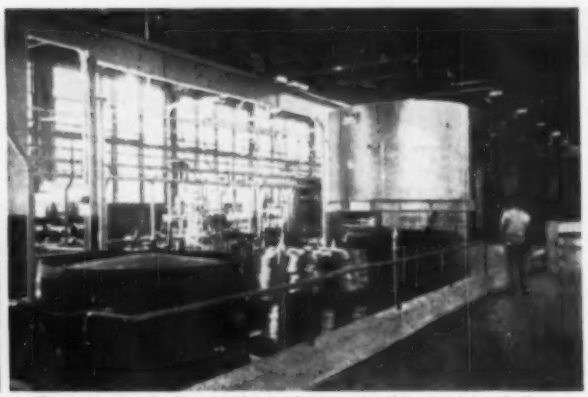
wherever heat is used in industry



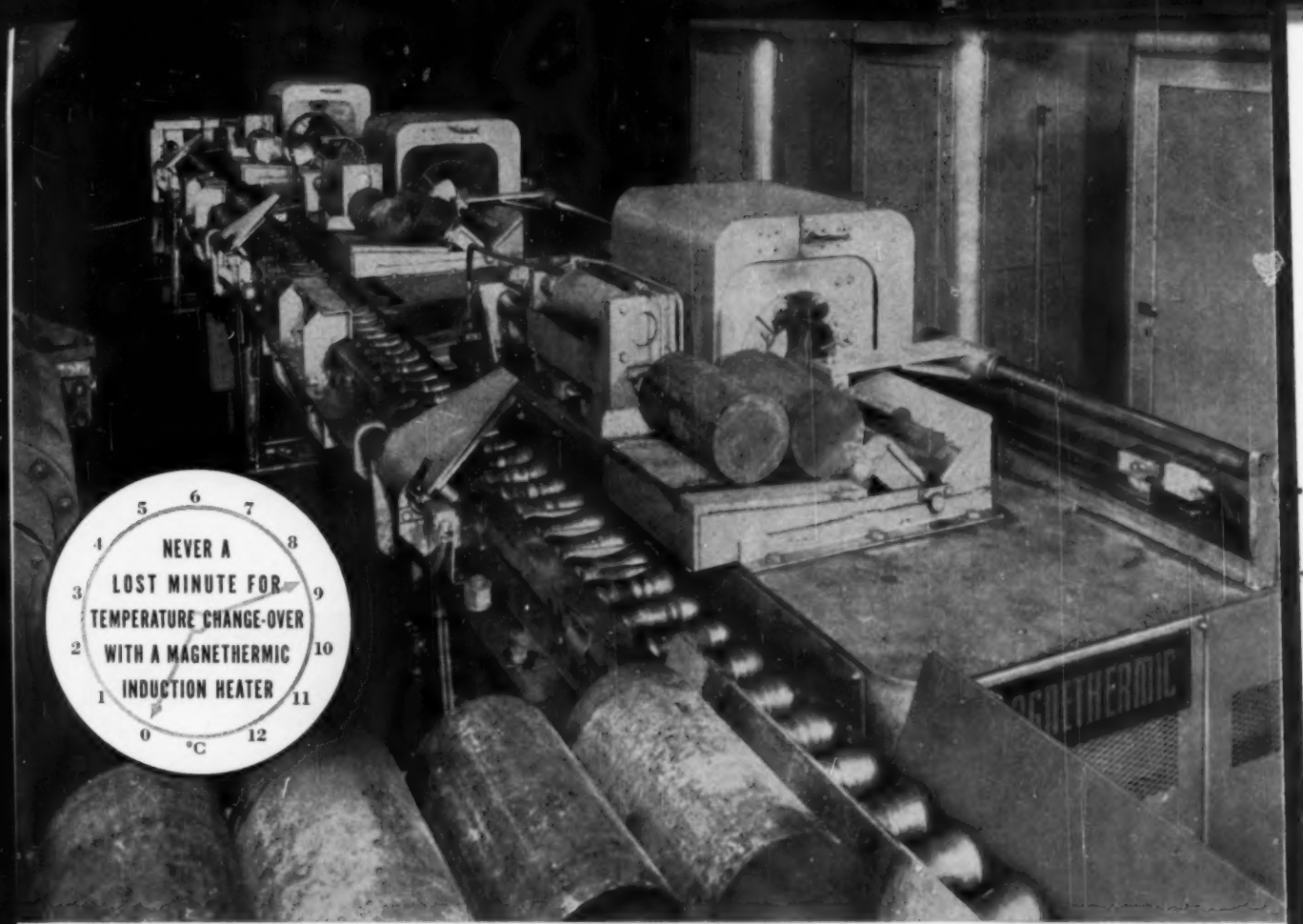
Surface high-speed furnace heats nonferrous billets for extrusion at a rate of 19,250 lbs/hr, with fine grain size.



"Super convection" cuts the cycle time in this precision bell annealer. Direct-fired heating's in the base.

Specified grain size of 0.040 mm is held easily in this Surface continuous bright annealer for copper tubing.

This direct-fired furnace has a rated production of 2500 lbs/hr of aluminum blocked forgings.



"This installation is Wolverine Tube, Division of Calumet & Hecla, Inc., Detroit, Michigan"

Three Magnethermics, 60 cycle, heating 8" x 15" copper and brass billets for a 3000-ton extrusion press. Each heater is individual of the other, operating from a common loading and unloading conveyor. One, two, or three heaters can be used, depending upon production requirements.

Flexibility for emergency orders - *you never have to plan ahead for a temperature change-over...*

SET THE DIAL — PRESS THE BUTTON — HEATED BILLET

You never have to backlog billets with a Magnethermic Induction Heater. Operator dials the temperature, presses the button, and a uniformly heated billet will be ready in moments. And the next billet and the next will be the same temperature. The Magnethermic heater also records the temperature of each billet so that you have a permanent record for checkback.

When a rush or emergency order upsets the day's schedule, the operator sets the dial to the new temperature and the Magnethermic is ready to deliver immediately. No costly shutdowns normally associated with fuel firing.

More than temperature can be changed over without production delay on a Magnethermic . . . size of billet or type of alloy, as well as temperature, can be adapted in minutes.

This flexibility more than offsets the higher original costs, as many users of Magnethermics have confirmed. Once you have an induction heater, you can forget about the billet heating for your forging presses, extrusion presses or rolling mills. No more stockpiling. No more backlogging. No more long shutdowns.

Any metal that can be heated can be heated by a Magnethermic Induction Heater . . . low, dual or high frequency. There are Magnethermics in operation for aluminum, beryllium, copper, columbium, magnesium, molybdenum, nickel and nickel alloys, platinum, carbon and alloy steels, titanium, and vanadium.

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This cleaner produces an attractive, uniform etch in a short time on all types of aluminum surfaces. Ahcal's outstanding advantage is its ability to dissolve large amounts of aluminum without forming undesirable scale or sludge.

Ahcal Deoxidizer ℞

Ideal to remove smut after cleaning and etching, and before painting. Its convenient powdered form makes it safer than liquid acids.

Ahcoloid Cleaners ℞

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#LC-3—An emulsifiable liquid pre-cleaner to remove oil, grease, and buffing residues.

#59-H-5—A cleaner for power washers.

LUSTREBRITE LIQUID 35—A new liquid soak cleaner developed specifically to remove buffing compound residues and fingerprints.

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1315. High-Temperature Alloy

New 8-page booklet on Haynes silicon nitride, designed to operate at temperatures over 3000° F. Applications. *Haynes Stellite*

1316. High-Temperature Alloy

Bulletin 106 gives data on Type 321 stainless and contains temperature range chart for six alloys. *Rolled Alloys*

1317. Humidity Instruments

New 22-page bulletin on indicating, recording and controlling wet and dry bulb instruments and psychrometers. *Bristol Co.*

1318. Induction Furnace

Folder R-61 on induction furnace for electric melting and holding of aluminum. *Ajax Engineering Corp.*

1319. Induction Heater

8-page bulletin on 60-cycle induction heater for aluminum, copper, brass and steel. Installations, billet heater selection chart for aluminum. *Magnethermic*

1320. Induction Heating

Folder on high-frequency induction heating includes diagrams of water-cooled, air-cooled and variable output work unit. *Cincinnati Milling Machine*

1321. Induction Heating

New brochure on low-frequency induction heating. Advantages and applications. *Electric Arc, Inc.*

1322. Induction Heating

High Frequency Review contains article on high temperature fatigue tests using induction heating. *Lepel High Frequency Laboratories*

1323. Induction Heating

60-page catalog tells of reduced costs and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

1324. Induction Heating

Brochure on induction heating furnace. Frequency chart. *Pittsburgh Induction Heating Co.*

1325. Industrial Equipment

12-page catalog on finishing systems, cleaning, pickling, rustproofing equipment, ovens, conveying equipment. *R. C. Mahon Co.*

1326. Inspection

Data on multi-frequency inspection of nonferrous and nonmagnetic metals. *Magnetic Analysis*

1327. Instruments

32-page Catalog 20-10 on electronic self-balancing instruments for indicating, recording, controlling. Instruments described and diagrammed. Principles of operation. *Foxboro*

1328. Investment Casting

August 1958, Vol. 1, No. 4, "Casting About with Misco", on factors which affect cost of investment castings. *Misco Precision Casting Co.*

1329. Iron Powders

New 48-page booklet on three types of iron powders. Applications, chemical composition, physical properties. 27 pages of graphs. *Metal Powder Div., Republic Steel*

1330. Iron Powders

New 12-page Bulletin No. 2 on iron powders. Properties of Plast/Iron, Plast/Steel, Plast/Nickel, Plast/Manganese and Plast/Silicon. *Plastic Metals Div.*

1331. Laboratory Equipment

New bulletin on cutting test specimens describes methods for different types of metals. Price list. *Sieburg Industries*

1332. Low-Alloy Steel

60-page book on high-strength low-

(*Continued on page 48-A*)

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With the recent trend in strip metal towards thinner and thinner gauges, Somers, a pioneer in thin strip for nearly 50 years, is naturally among the leaders in rolling *ultra-thin* strip. But in addition to rolling production quantities of strip as thin as can be obtained anywhere in the world, Somers utilizes exclusive techniques and equipment to make sure that every foot of metal is up to the most exacting standards.

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NEARLY FIFTY YEARS

3. Experience exclusively with thin strip metals gives Somers an unmatched background in engineering *ultra-thin* strip to meet all special requirements.

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And, through Mr. Tubes, you can save both time and money by utilizing B&W's "one-source" supply. You get a matched piping system — both pipe *and* fittings, in the materials you need — when you need them. Buying and delivery are more closely controlled, too. Check with Mr. Tubes on your next job. He can be reached at any B&W Tubular Products Division District Sales Office. The Babcock & Wilcox Company, Tubular Products Division, Beaver Falls, Pennsylvania.

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Seamless welding fittings and forged steel flanges, seamless and welded tubular products, solid extrusions — in carbon, alloy, stainless steels and special metals.

(Continued from page 47)

alloy steel. Properties, fabrication and uses. *U. S. Steel*

1333. Lubricant
Bulletin 426 on use of colloidal graphite for forging, wire drawing, piercing, drawing, extrusion and other metalworking operations. *Acheson Colloids*

1334. Lubricant
New 8-page Bulletin 304 on use of molybdenum disulfide lubricant in cold forming, cold heading and other applications. Case histories. *Alpha Molykote*

1335. Lubricants
New booklet giving information on company's complete line of industrial products. *Sun Oil Co.*

1336. Magnetic Materials
New 64-page book on electronic, magnetic and electrical alloys. Engineering properties and fabrication characteristics. *Carpenter Steel Co.*

1337. Manganese
Technical Data Bulletin 201 on electromanganese and nitrelmang. Product characteristics. Composition. *Foote Mineral*

1338. Metal Sorting
Data on nondestructive sorting tool for raw, semifinished or finished parts. *J. W. Dice*

1339. Metallizing
Folder on types, sizes and prices of metallizing wires. *Spra Rod Corp.*

1340. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance*

1341. Microscopes
40-page catalog on metallographs, metallurgical, toolmakers, stereoscopic, polarizing, phase and other microscopes. *Unitron Instrument Div., United Scientific*

1342. Mixers
20-page booklet B-103 on fixed mounting propeller-type fluid mixers. Mixing capacities, standard sizes and speeds. *Mixing Equipment*

1343. Monel
Booklet on engineering properties of cast Monel. *International Nickel Co.*

1344. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

1345. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

1346. Nuclear Forgings
New 6-page brochure on carbon, alloy and stainless steel forgings for nuclear reactor applications. *U. S. Steel Corp.*

1347. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

1348. Optics
Catalog on optics for industry. Comparators, lenses, prisms, microscopes, magnifiers. *Edmund Scientific*

1349. Photographic Films
Catalog of motion picture, radiographic and industrial films, photographic papers and luminescent chemical products. *DuPont*

1350. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

1351. Plated Strip
Bulletin on plated metal strip. Plating thicknesses and variations possible. *Sylvania Electric*

1352. Plating
Data and specification sheet covering tin plating a wide range of nonferrous thin strip metals. *Somers Brass Co.*

1353. Plating Thickness Tester
Data sheets give ranges, principle of operation of nondestructive thickness tester. *Unit Process Assemblies*

1354. Portable Recorder
Bulletin 60-100 on instrument for recording any measurement that can be converted to a change in resistance of d. c. millivoltage. *Thermo Electric*

1355. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

1356. Press
Bulletin No. 1200 on 50-ton multiple-motion powder metal press. Operating characteristics, physical specifications. *F. J. Stokes*

1357. Presses
Data on mechanical and hydraulic powdered metal presses 8 to 500-ton capacities. *Haller, Inc.*

1358. Presses
New 6-page Bulletin 340-C on aluminum extrusion presses. *Watson-Stillman*

1359. Quenching
16-page booklet on modified and full marquenching procedures. Hardness and dimensional control data, cooling curves, case histories. *Sinclair Refining Co.*

1360. Radiation Badges
Data on badges which record exposures to radiation. *Picker X-Ray Corp.*

1361. Radiation Equipment
Radiation Digest, March-April 1957, contains cost sheet comparing costs of inspection by electron or gamma-ray irradiation equipment. *General Electric, X-Ray Dept.*

1362. Refractories
24-page manual on mortar preparation and general instructions. Bibliography. *Lumnite Div.*

1363. Refractories
12-page catalog shows properties of impervious recrystallized alumina and impervious mullite. Shapes into which each is fabricated. *Morganite, Inc.*

1364. Refractories
New 16-page Catalog 1795, "Crucibles for Metal Melting". Physical and chemical characteristics, uses and availability of various refractory products. *Norton*

1365. Resistance Alloy
16-page catalog on 60-16 nickel-chromium-iron alloy. Heating element design factors. *Hoskins Mfg.*

1366. Resistance Thermometers
New 36-page Catalog EN-S4 on resistance thermometers for temperatures up to 1000° F. Design and construction, sizes. Applications. *Leeds & Northrup Co.*

1367. Rhodium Plating
Data on rhodium sulfate and on limited time tests of this rhodium concentrate. *Technic*

1368. Rust Prevention
16-page booklet on corrosion testing, standard rust preventives. Selection chart. *E. F. Houghton & Co.*

1369. Rust Prevention
Nine bulletins in one folder on rust prevention. Theory of corrosion. *Production Specialties*

1370. Rust Preventive
New bulletin on wetting agent and emulsifier for use as a rust preventive and corrosion inhibitor. *Swift & Co.*

1371. Sand Control
32-page book on defects and troubles in foundry and how to remedy them through sand control. *Claud S. Gordon*

1372. Shear
Bulletin on bar and billet shear for

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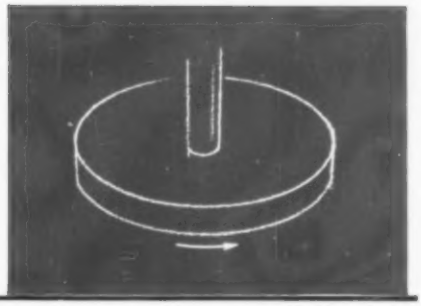

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Production rates frequently bog down when floor space limitations prohibit large equipment purchases.

That's why—when the problem is heat treating—many companies turn to Holcroft for answers. Experience—imaginative engineering—versatility of products—all team up to provide answers.

For example, the solution to the problem above could conceivably be a rotary furnace; with one or two doors for loading and unloading and a rotating hearth which carries the stock through the heat treat cycle. The hearth can be of a heat-resistant alloy or a refractory material—can be suspended from above or supported from below. Rotary furnaces can be tunnel-type, grid-type, drum-type, or rotating retort.

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"Blazing the Heat Treat Trail." It's bound to give you food for thought.

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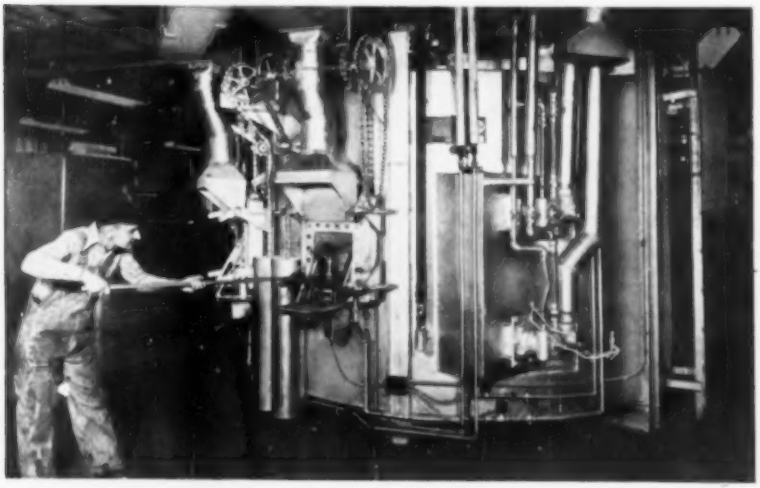

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Here's "Stepless" Electric Proportioning Control with Proof of Performance

Your best guide to selecting "stepless" electric proportioning controls is to rely on the unit backed by an unbroken record of success on *thousands of installations.* You take out the guesswork when you choose the Wheelco Model 407 electric proportioning controller — it stands out clearly above the rest.

Wheelco not only pioneered saturable reactor control of power input but maintains leadership by giving you units built for long life and simplified maintenance. For example, standard vacuum tubes readily replaced by local electronic supply houses have exceptionally long life because they operate well below their maximum output. Plug-in components make inspection and service quick and simple.

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rounds, squares, flats, billets and structurals. Hot or cold operation. *Hill-Acme*

1373. Shell Molding

New 4-page Data Sheet SF-1128 on silicones for the shell molding process describes three different products. *Silicones Div., Union Carbide*

1374. Slitting

New 48-page Bulletin 571 on rotary slitting knives, trimming knives, pipe and tube cut-off knives and others. Standard and special types of high speed steel and carbide tipped milling cutters. *Cowles Tool Co.*

1375. Slitting

76-page handbook on multiple rotary slitting lines. Design, selection and operation of slitters. Specifications and capacity tables. *Yoder Co.*

1376. Sodium

28-page booklet on using sodium in dispersed form tells how dispersions are prepared and handled, and their advantages. *Ethyl Corp.*

1377. Spectrometer

Bulletin on Atomcounter direct reading spectrometer describes instrument and pulse computer system. *Jarrell-Ash*

1378. Stainless Steel

New 8-page booklet on extra-low-carbon stainless steel. Chemical analyses, design, fabrication, mechanical properties. *Armco*

1379. Stainless Steels

New 28-page booklet on special purpose stainless steels. Types, finish characteristics, uses, corrosion data, cleaning agents. *Washington Steel*

1380. Steels

Reference data sheet on Vasco M-2 (tungsten-molybdenum) high speed steel. Heat treatment, compositions, applications. *Vanadium-Alloys Steel Co.*

1381. Stereomicroscopes

38-page catalog D-15 shows value of three-dimensional microscopes for industrial assembly lines and research laboratories. *Bausch & Lomb Optical*

1382. Temperature Control

New 8-page Bulletin 838 on temperature control in gas and vapor chromatography. Temperature programming. *Burrell*

1383. Testing

Folder on laboratory facilities for handling research problems involving microscopy, X-ray. *Ernest F. Fullam, Inc.*

1384. Testing

10-page article, Bulletin M-2, on testing copper single crystals. *Instron Engineering Corp.*

1385. Testing Equipment

80-page illustrated catalog lists over 130 testing and measuring tools for laboratory and production-line use. *General Electric*

1386. Testing Machines

New 8-page Bulletin RG-14-55 on testing machines and instruments. *Riehle*

1387. Testing Machines

Bulletin on Brinell hardness, ductility, compression, tensile, universal, transverse, hydrostatic proving instruments. *Steel City Testing Machines*

1388. Thermocouples

New bulletin F-5228-3 on construction and application of thermocouples and radiation detectors to industrial control. How to check, make, select and size thermocouples. *Wheelco*

1389. Thickness Gage

Folder on pocket-size gage. How to use it. *Ferro Corp.*

1390. Thickness Gage

New bulletin on noncontacting thickness gage. Range, sensitivity, speed of response. *Nuclear Systems, Budd Co.*

1391. Titanium

24-page fact file gives physical and mechanical properties, metallurgy, corrosion properties, machining, forming and welding data. *Mallory-Sharon Metals*

1392. Tool Steel

Chart gives stock sizes, analyses and properties of A2 and O1 precision ground tool steel. *Uddeholm*

1393. Tool Steels

12-page booklet on tool steels for forging operations. Basic forging operations, equipment. Heat treatment of steels for hot forging. *Crucible Steel*

1394. Tool Steels

16-page booklet on tool steels, their application and heat treatment for the die casting process. *Crucible Steel*

1395. Tubing

16-page Bulletin No. 12 on types, grades, lengths, finishes and general characteristics of small diameter stainless steel, nickel and nickel-alloy tubing. *J. Bishop & Co.*

1396. Tubing

New book on production of seamless and welded tubing. Forging and fabricating operations. *Ohio Seamless Tube*

1397. Tubing

New 8-page Bulletin TB-365-A on stainless mechanical tubing, seamless or welded. Specifications, heat treatment, sizes, shapes. *Tubular Products Div., B & W*

1398. Ultra Strength Steel

Results of three-year research and test program evaluating properties of Type 4340 steel for aircraft structures. *International Nickel*

1399. Ultrasonics

Data sheets on high-power ultrasonic generators for mass production, and ultrasonic scrubber. *Acoustica Associates*

1400. Ultrasonics

Data sheet on gages for thickness measurement, coating measurement, inspection. *Branson Instruments*

1401. Vacuum Melted Alloy

New 8-page Engineering Data Brochure VM-104 on vacuum melted alloys. Mechanical and physical properties. Stress-rupture data. *Metallurgical Products Dept., G.E. Co.*

1402. Vacuum Melting

8-page bulletin on production and testing equipment for vacuum melting. Advantages of process. *Utica Metals Div.*

1403. Welder

New brochure on semi-automatic welder. Construction features. Applications in representative industries. *Wall Colmonoy*

1404. Welding Stainless

New 12-page booklet—a guide to better welding of stainless steels. In question and answer form. *Arcos*

1405. Wire Cloth

94-page catalog on line of industrial wire cloth, screen and wire cloth products. Types, sizes, applications. Metals and alloys used, stainless compositions, corrosion tables. *Cambridge Wire Cloth*

1406. X-Ray Film

Technical data on line of Structurix films. *Gevaert Co.*

1407. X-Ray Films

6-page folder on industrial X-ray films and processing chemicals. Exposure characteristics. Selection of best film for each job. *Ansco*

1408. Zinc Coating

8-page booklet on zinc-coated steel sheets. Fabrication, uses, advantages in heating, ventilating and air conditioning. *Weirton Steel*

1409. Zirconium

8-page brochure on zirconium's corrosion resistant properties. Applications based on this property. *Carborundum Metals Co.*

DECEMBER, 1958

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1189	1210	1231	1252	1273	1294	1315	1336	1357	1378	1399
1190	1211	1232	1253	1274	1295	1316	1337	1358	1379	1400
1191	1212	1233	1254	1275	1296	1317	1338	1359	1380	1401
1192	1213	1234	1255	1276	1297	1318	1339	1360	1381	1402
1193	1214	1235	1256	1277	1298	1319	1340	1361	1382	1403
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1195	1216	1237	1258	1279	1300	1321	1342	1363	1384	1405
1196	1217	1238	1259	1280	1301	1322	1343	1364	1385	1406
1197	1218	1239	1260	1281	1302	1323	1344	1365	1386	1407
1198	1219	1240	1261	1282	1303	1324	1345	1366	1387	1408
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1202	1223	1244	1265	1286	1307	1328	1349	1370	1391	
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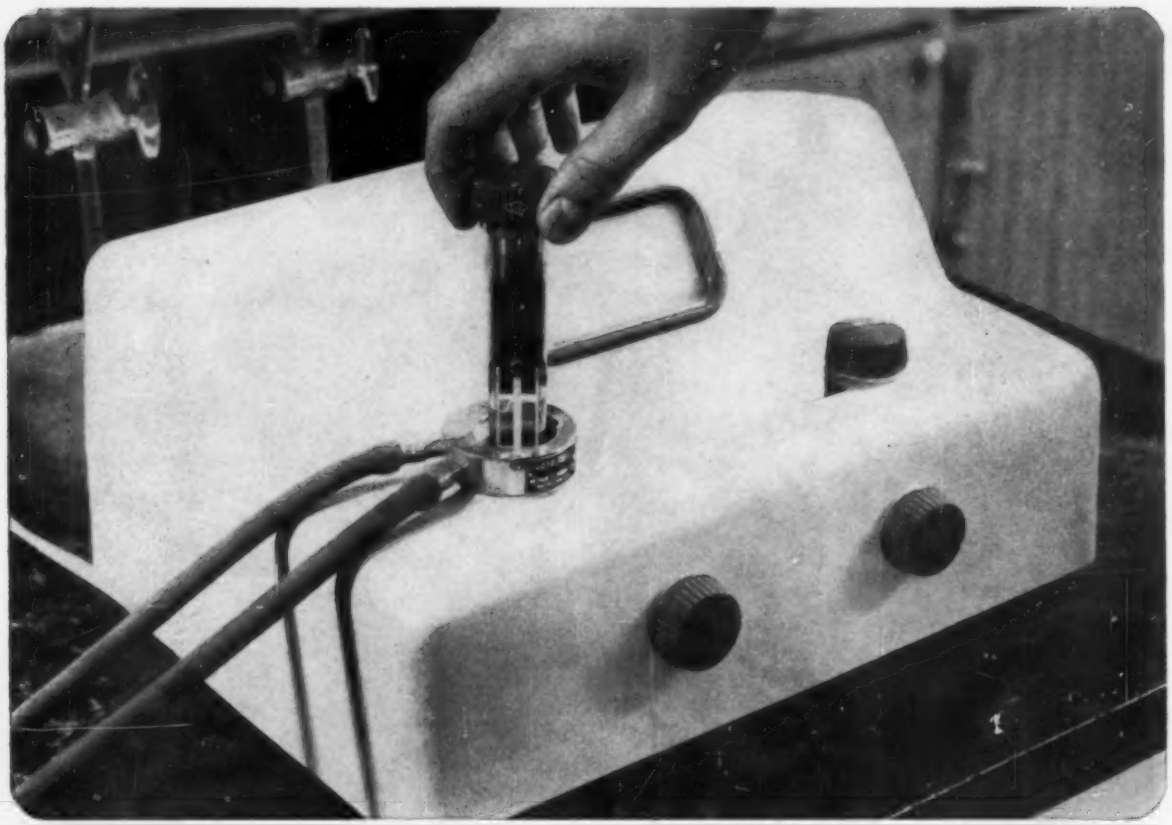
***Experience**—the added alloy in **Allegheny Ludlum** tool steels*



COLORIMETER (inherently extremely accurate) determines percentages of molybdenum, tungsten, cobalt and manganese in A-L tool steel to insure consistent, high quality.

Colorimeter measures exact chemical composition of Allegheny Ludlum tool steel melts

Accurate adjustment of alloys guarantees uniform heat treatment, predictable dimensional changes, reduced grinding, standardized machining operations.

Close control of molybdenum, tungsten, cobalt and manganese is at the heart of a good tool steel melt. In addition to the usual testing methods, Allegheny Ludlum's chemical laboratory checks these metals with Colorimetry because of its inherent, extreme accuracy.

On the basis of the Colorimeter's findings, it is possible to make carefully calculated furnace additions of ferro-alloys, insuring precise control over chemistry. This guarantees your receiving the *exact* analysis order after order, providing *uniformity of heat treatment, predictable dimensional changes, reduced grinding and standardized machining operations.*

WSW-7262

Colorimetry is but one step toward careful control over composition. Allegheny Ludlum also sets exacting purchasing specifications on raw materials and scrap. Quality Control checks all incoming orders to see that they conform with these specifications. Another guard toward your getting your exact specifications: each ingot bears a metal tab showing heat number.

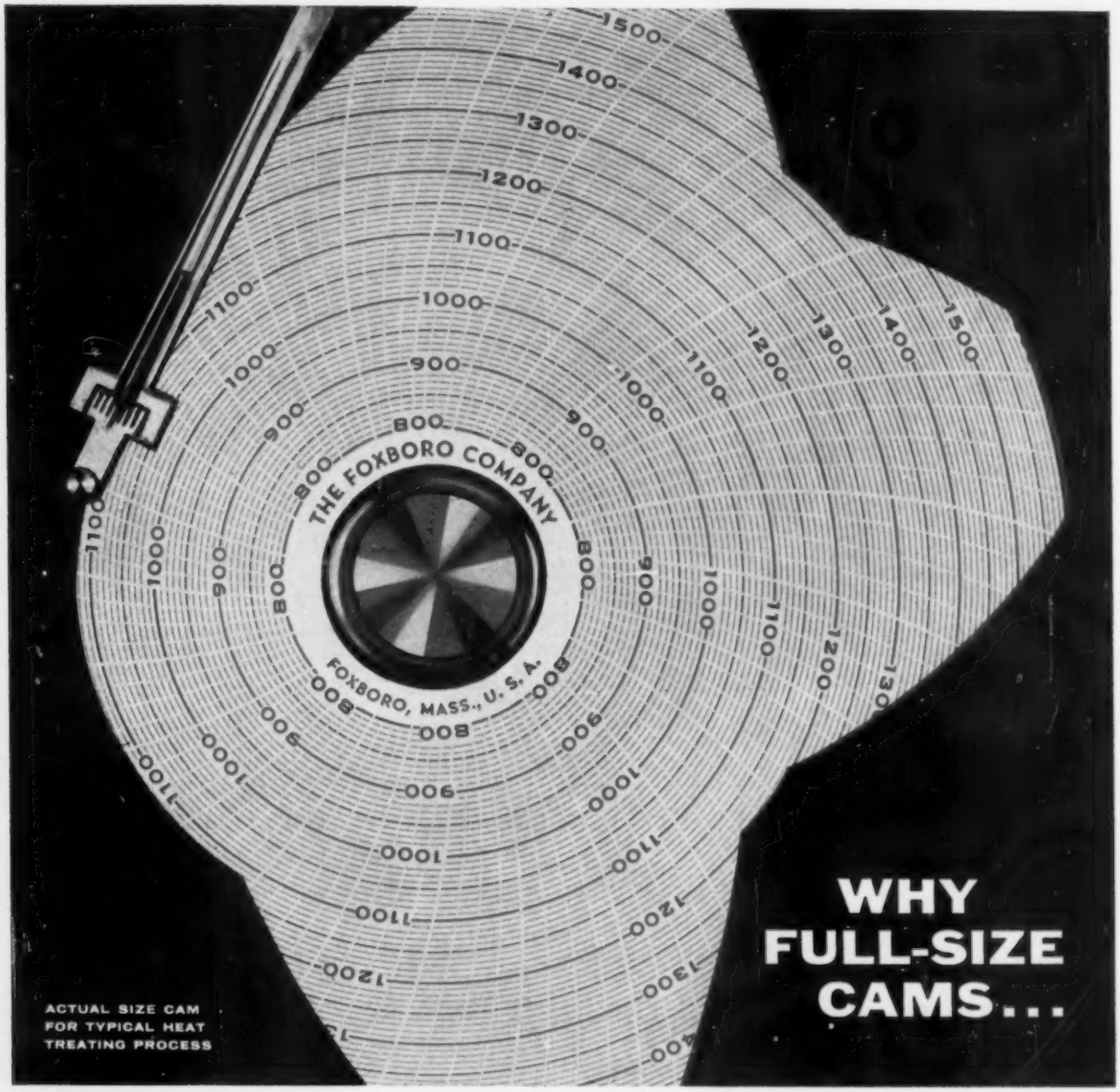
Allegheny Ludlum stocks a complete line of tool steel sizes and grades. Call your nearest A-L representative; you'll get quick service and counsel on such problems as heat treating, machining, grade selection, etc. Or write for A-L's publication list which gives full data on the more than 125 technical publications offered. They'll make your job easier.

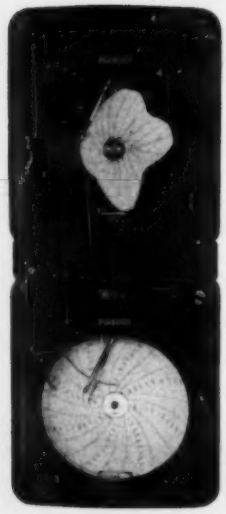
ALLEGHENY LUDLUM STEEL CORPORATION, Oliver Bldg., Pittsburgh 22, Pa. Address Dept. MP-12

ALLEGHENY LUDLUM

Tool Steel warehouse stocks throughout the country... Check the yellow pages

every grade of tool steel... every help in using it





Foxboro two-case Cam-Set Program Controller. (Single case controllers also available.)

. . . give you closer Temperature Program Control!

For heat treating processes requiring special cycles, the Foxboro Cam-Set Program Controller is the ideal solution.

Foxboro Cam-Set Controllers use FULL-SIZE cams—as large as the recording chart itself. Full size cams are easily cut for greater accuracy . . . cam follower is more sensitive.

Cam-Set Controllers are designed with cam mechanism and recorder-controller in separate cases. Cams may be changed without touching the recording chart. And the cam and chart can be rotated at different speeds.

Foxboro Cam-Set Program Controllers are available with thermocouples or resistance bulbs for temperatures from −300°F to +2800°F; or with filled thermal systems from −450°F to +1000°F. They may use any type of automatic control: on-off, proportional, or Rotax electric control.

Find out about this simple, precise automatic control for complicated heat treating programs.

Bulletin 5A-12 has all the details. Write for your copy today. **The Foxboro Company, 5212 Neponset Avenue, Foxboro, Massachusetts.**

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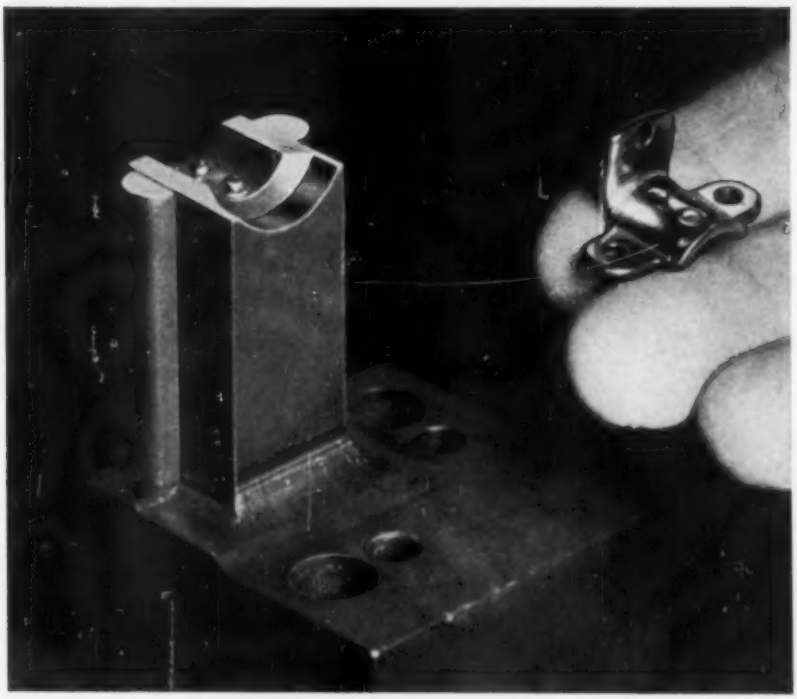
CAM-SET PROGRAM CONTROLLER

Tool Steel Topics

BETHLEHEM STEEL

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

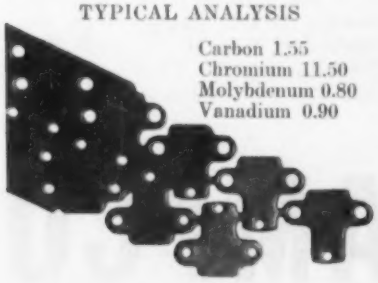


1½ million pieces with Lehigh H ...that's a long run in any league!

At Harvey Hubbell, Inc., Bridgeport, Conn., they were using a competitive grade of tool steel to form cord-clamp sections made from Grade 1010 steel strip. But each time they hit an average figure of 700,000 pieces, the die cracked, and had to be replaced. The manufacturer decided to call in Lindquist Steels Inc., a local distributor of Bethlehem tool steel.

TYPICAL ANALYSIS

Carbon 1.55
Chromium 11.50
Molybdenum 0.80
Vanadium 0.90



"With the finished part only .060 in. thick, we ought to do better than 700,000 pieces. What do you suggest?"

The distributor studied the operation, the cracked die, and the finished part. "I'd recommend Lehigh H," he said. "It has the strength you need in a forming operation of this sort." The Lehigh H was put on the job and produced 1½ million pieces without any trouble.

Lehigh H is our high-carbon, high-chromium, air-hardening tool steel. It's a grade with outstanding wear-resistance and toughness. And it's also a deep-hardening steel with high compressive strength.

The best way to evaluate Lehigh H is by putting it to work—not in an easy job, but in a tough one. Your Bethlehem tool steel distributor carries Lehigh H in stock, and will see that it's delivered promptly. Get in touch with him.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

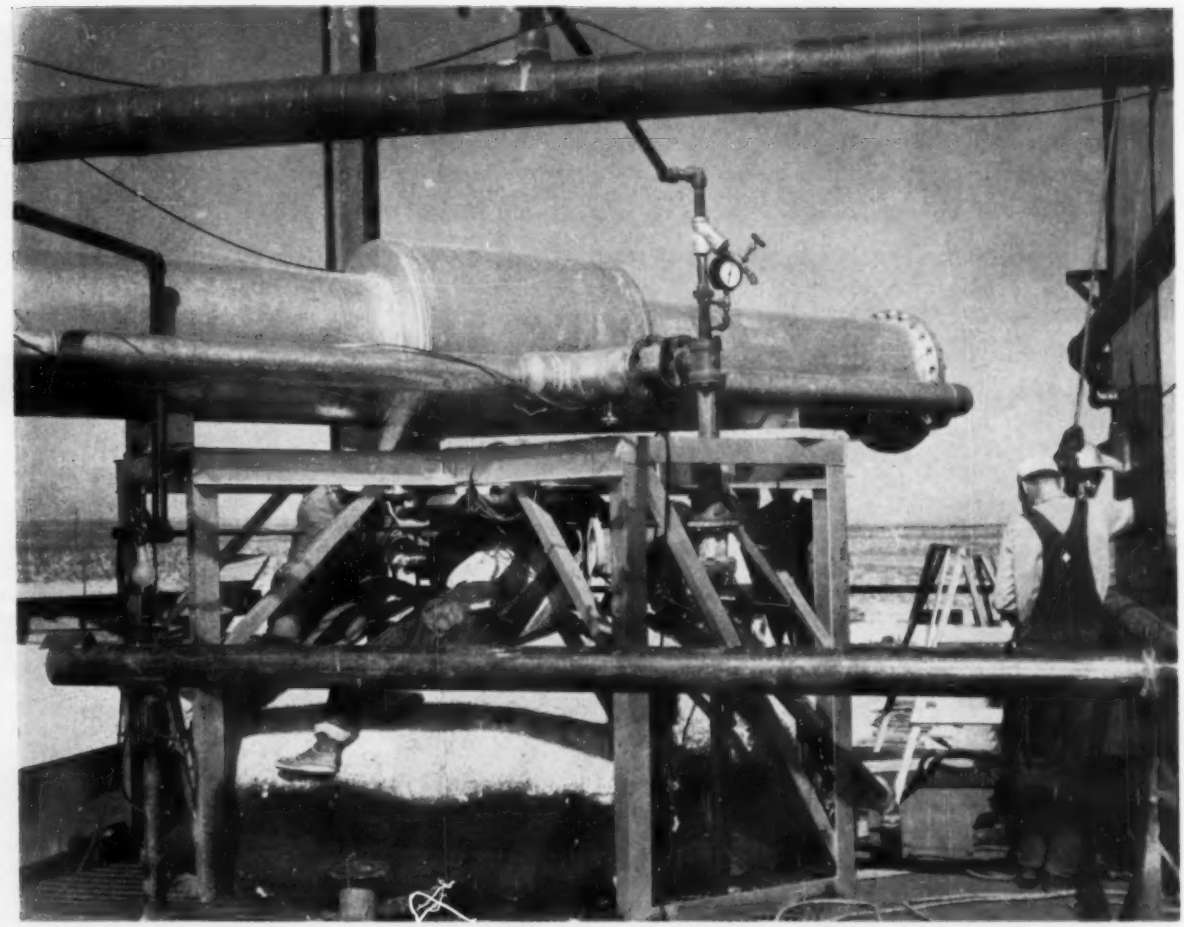
Don't Use Fresh Water For Quenching Tools

Fresh water, regardless of its source, contains dissolved gases which make it unsuitable for quenching tools. When tools are quenched in fresh water, gas is liberated at the surface of the tool. Gas pockets thus formed may prevent contact between tool and water, resulting in soft spots from ineffective quenching. Soft spots are undesirable because of their low hardness, and also because a quench which produces them may also cause cracking of the tools.

Soft spots, and tool cracking associated with soft spots, can be avoided by quenching in water which has been previously boiled, to remove the dissolved gases. If water cannot be boiled, quench a large amount of hot "dummy" material to expel the gases. As a further precaution against soft spots, it is preferable to use a 10 pct brine solution instead of water. It is also suggested that the dissolved gases be expelled from the brine solution before use.

USE DURAMOLD FOR COLD-HOBBING

Bethlehem's Duramold tool steels, in Grades A and B, are ideal for cold-hobbing plastic dies because they are free from injurious surface and internal defects. Duramold A, an air-hardening grade, is annealed to 109 max Brinell. Duramold B hardens in oil, and hobs more readily than Duramold A. It is annealed to 100 max Brinell, and has an addition of boron to increase the core strength.



Erecting a crystallizer at a potash refinery in Carlsbad, N. M. operated by the U. S. Potash Co., a division of U. S. Borax & Chemical Corp. This is one of seven crystallizers that were shop- and field-fabricated, then field-assembled by welding. They were not stress-relieved or heat-treated. There has been no stress-corrosion cracking in the nine months these units have been in service at the potash refinery.

NEW Ampco Metal Grade 8 stops stress-corrosion cracking!

Important changes have been made in Ampco Metal Grade 8! It's *entirely new*—and completely obsoletes old ideas about fabricating copper-base alloy equipment to handle steam and corrosive media at elevated temperatures.

Now, with new, patented Ampco Metal Grade 8, you can . . .

1. Field-fabricate *without stress-relieving!*
2. Make field repairs, changes, and alterations *without heat treatments!*
3. Readily weld with any electric welding process! A. No pre-heat. B. No post-heat. C. No hot-short cracking!

At one major oil refinery, field-assembled piping of Ampco Metal Grade 8 has handled hot sulphuric-acid sludge for a year and a half without stress-corrosion cracking. Driers in a paper mill have handled 350° F steam at 125-lbs. pressure for more than a year without stress-corrosion cracking.

Let us prove it to you. Talk to your Ampco field engineer. Or write for details. *Ampco Metal, Inc., Dept. 21L, Milwaukee 46, Wis. West Coast Plant: Burbank, Calif. — Southwest Plant: Garland (Dallas County), Texas.*

YS-1

AMPCO®

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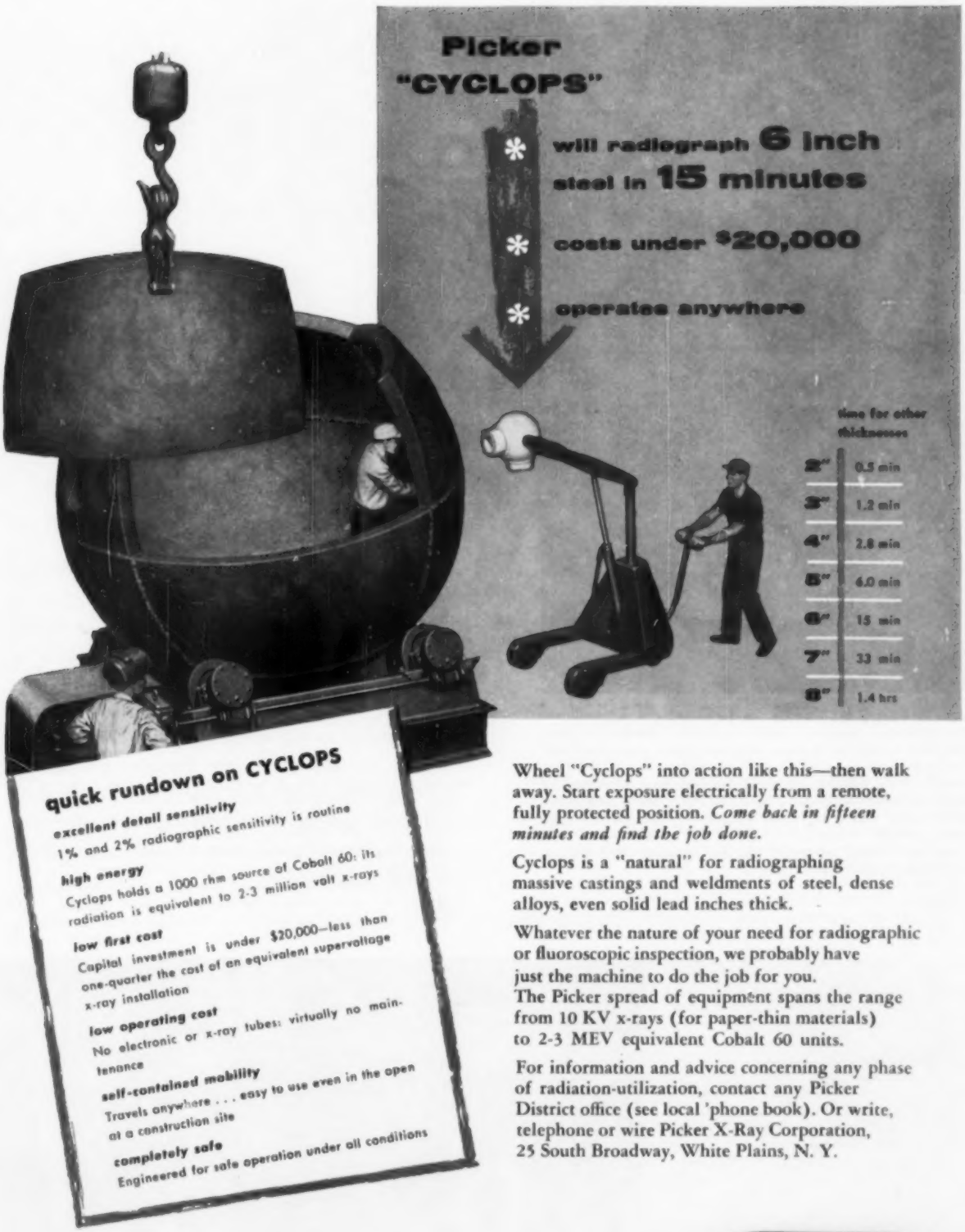

Picker
"CYCLOPS"
* will radiograph 6 inch steel in 15 minutes
* costs under $20,000
* operates anywhere
time for other thicknesses
2" 0.5 min
3" 1.2 min
4" 2.8 min
5" 6.0 min
6" 15 min
7" 33 min
8" 1.4 hrs
quick rundown on CYCLOPS
excellent detail sensitivity
1% and 2% radiographic sensitivity is routine
high energy
Cyclops holds a 1000 rhm source of Cobalt 60: its radiation is equivalent to 2-3 million volt x-rays
low first cost
Capital investment is under $20,000—less than one-quarter the cost of an equivalent supervoltage x-ray installation
low operating cost
No electronic or x-ray tubes: virtually no maintenance
self-contained mobility
Travels anywhere . . . easy to use even in the open at a construction site
completely safe
Engineered for safe operation under all conditions

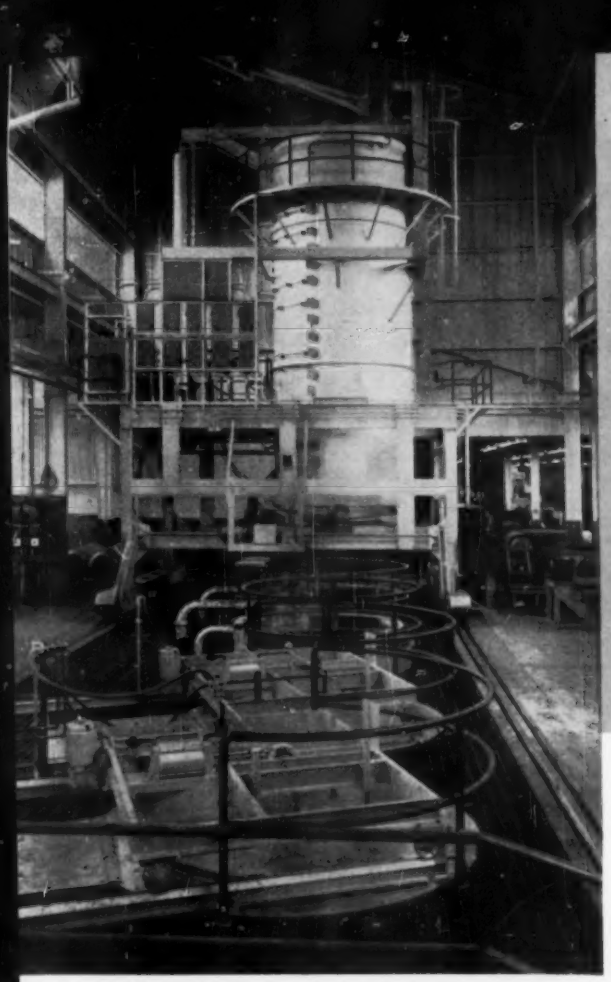
Wheel "Cyclops" into action like this—then walk away. Start exposure electrically from a remote, fully protected position. *Come back in fifteen minutes and find the job done.*

Cyclops is a "natural" for radiographing massive castings and weldments of steel, dense alloys, even solid lead inches thick.

Whatever the nature of your need for radiographic or fluoroscopic inspection, we probably have just the machine to do the job for you. The Picker spread of equipment spans the range from 10 KV x-rays (for paper-thin materials) to 2-3 MEV equivalent Cobalt 60 units.

For information and advice concerning any phase of radiation-utilization, contact any Picker District office (see local 'phone book). Or write, telephone or wire Picker X-Ray Corporation, 25 South Broadway, White Plains, N. Y.

if it has to do with radiation it has to do with Picker x-ray



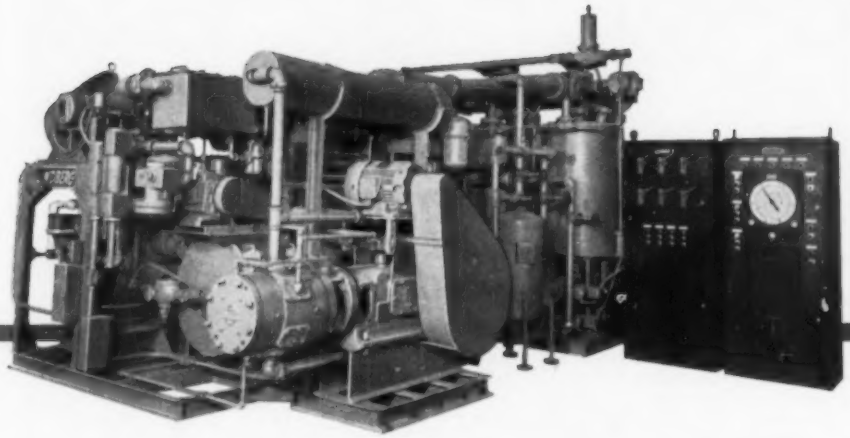
This year alone Lindberg has developed five major improvements in the application of heat to industry

Improved Gantry type hardening furnace for missiles. Latest development of standard Gantry type, this huge furnace provides more economical, faster production and improved metallurgical qualities in treating missile parts. The installation consists of the electric, controlled atmosphere, Gantry type furnace and two draw furnaces, a hot water wash tank, a salt bath quench and a nitrogen generator. The Gantry type furnace moves under power over the entire installation to load or unload at any of the pit stations. Both design and installations by Lindberg.

Not so many months back business wasn't booming in the metalworking field. But through this period, Lindberg went steadily ahead with its policy of helping make business better by constantly seeking better ways to apply heat to industry. Fortunately, Lindberg has the research experts, the designers, the engineers to implement this policy. As evidence, shown on these pages are five major Lindberg developments of the past twelve months. In their respective spheres these offer industry more efficient, more productive, more economical industrial heating equipment.

Induction Aluminum Billet Heater. This exclusive new Lindberg induction billet heater provides aluminum extruders with an accurate, efficient solution to a difficult production problem. It features "Metered BTU's", an improved control system for heating aluminum billets. The heating rate of billet is controlled and each billet automatically delivered to the die-casting machine at the exact temperature required for most efficient extrusion.

Full information on any of these new Lindberg developments is available from Lindberg Engineering Company, 2448 W. Hubbard St., Chicago 12, Ill.



Hyni Nitrogen Generator. This Lindberg Hyni nitrogen atmosphere generator is the latest development in gas processing and assures nitrogen of higher purity than has ever before been achieved by other processes. It is the first unit to provide low cost, high purity nitrogen by a dry, completely automatic process. It is suitable for any application where a high nitrogen, CO_2 free, dry atmosphere is required. The unit functions automatically, and once the generator is started, the entire operation is completely automatic and continuous.

Over the years Lindberg has consistently pioneered major advancements in industrial heating equipment . . . the famous Cyclone furnace, applying the first 100% forced convection heating principle . . . the first high temperature (2200° F.) endothermic generator . . . the development of controlled atmosphere generators, the creation of dew point equilibrium curves to establish proper atmosphere values and the exclusive Lindberg Carbotrol to maintain these values automatically . . . the "dimple" vertical radiant tube for fuel fired furnaces . . . the revolutionary CORRTHERM electrical heating element. Lindberg equipment and Lindberg planning can help you find the most effective answer to any problem of applying heat to industry. We cover the field, heat treating, melting and holding, brazing, enameling furnaces, ceramic kilns, high frequency units, and are in the ideal position to recommend just the type of equipment most suitable for your needs. Consult your local Lindberg Field Representative (see the classified phone book) or get in touch with us direct.

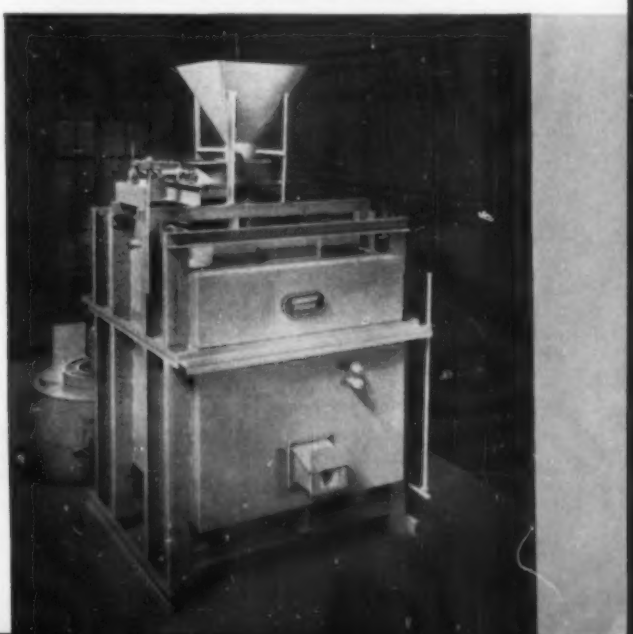
Lindberg Engineering Company

2448 West Hubbard Street, Chicago 12, Illinois

Los Angeles Plant: 11937 S. Regentview Avenue at Downey, Calif.

Induct-O-Ring Rotary Salt Bath Furnace. Offering for the first time an electric salt bath furnace that can be shut down over night or week end and regain efficient operating temperature quickly. Positive quality control is provided by rotary action of furnace and variable speed drive which insure exactly same time in bath for all parts. Gives precise temperature uniformity and control unequalled by any other salt bath furnace design. Offers greatly lowered operating, maintenance and initial investment costs compared with standard externally heated pot or electrode types.

Electric Controlled Atmosphere Dry Hearth Melting Furnace. This new Lindberg-Fisher Melting Furnace operates electrically and oxidation of aluminum, or melt loss, is reduced because the entire system can be pressurized with atmosphere. The only oxides incurred are those from the surface of the scrap, as charged. The furnace contains a sloping silicon carbide dry hearth which directs the molten aluminum through a covered trough into the companion holding furnace. Substantial savings in lower melt loss and maintenance is low. Particularly applicable for scrap with steel inserts.



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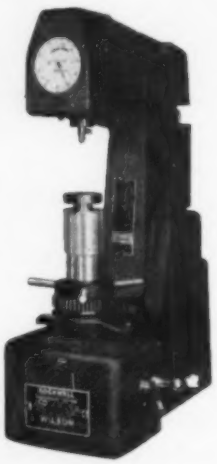
Equipment for *EVERY Hardness Testing Requirement*

WILSON "ROCKWELL" HARDNESS TESTERS ... ACCURATE AS A PRECISION BALANCE



No matter what your hardness testing requirements are, there's a WILSON "ROCKWELL" instrument to do the job. Choose from this complete selection of hardness testers:
"ROCKWELL"—for most hardness testing functions.
Superficial—for extremely shallow indentations.
Twintester—combines functions of "ROCKWELL" and "ROCKWELL" Superficial testers.
Semi-Automatic (manual feed) and Fully Automatic—for automatically classifying tested pieces as CORRECT, TOO HARD, or TOO SOFT—at test rates up to 1000 pieces per hour.
Special Machines—for testing large objects, obtaining internal readings, and other unusual applications.

ALL WILSON "ROCKWELL" hardness testers provide these advantages:
Accurate performance—precision built, with exact calibration, for consistently correct results.
Long life—durable as a machine tool.
Easy operation—even an unskilled operator can get perfect readings. All controls conveniently grouped.
Easy maintenance—interchangeable mechanisms, with spindles mounted on oil-less bearings.

DIAMOND "BRALE" PENETRATORS ... perfect testing every time

A perfect diamond penetrator is essential to accurate hardness testing. Since one point of hardness on the "ROCKWELL" scale represents only 80 millionths of an inch penetration—only 40 millionths on a Superficial tester—the slightest imperfection will cause a false reading.

Only *perfect* Wilson Diamond Brale Penetrators are sold. Each diamond is flawless, with no chips or cracks. It's cut to an exact shape. Microscopic inspection of every diamond—one at a time—assures this perfection—and assures you of accurate hardness testing every time.

TUKON TESTER ... for precision MICRO & MACRO testing

The TUKON Tester measures extremely shallow indentations. It's used, for instance, by manufacturers of watches, hairsprings, needles, and fine wire. Laboratories use the TUKON for tests on individual crystals or particles of microscopic size. Producers of coatings, film, ceramics, and many other materials have made good use of the TUKON.

Three models are available to meet your individual requirements. TUKON Testers use both the Knoop and 136° Diamond Pyramid Indenter. Each TUKON Tester is a self-contained hardness testing instrument— no accessory equipment is needed. Knife edges and levers of fixed length are used throughout for application of exact load and freedom from internal friction.

A COMPLETE LIBRARY of helpful information

A wide variety of bulletins describes the many instruments, accessories, and services Wilson offers. Write for your choice:
DH-325—WILSON "ROCKWELL" Hardness Testers • **DH-326**—"ROCKWELL" Superficial Hardness Testers • **DH-327**—Special "ROCKWELL" Testers, including Automatic and Semi-Automatic models • **DH-7**—TUKON Applications • **DH-328**—TUKON Testers.

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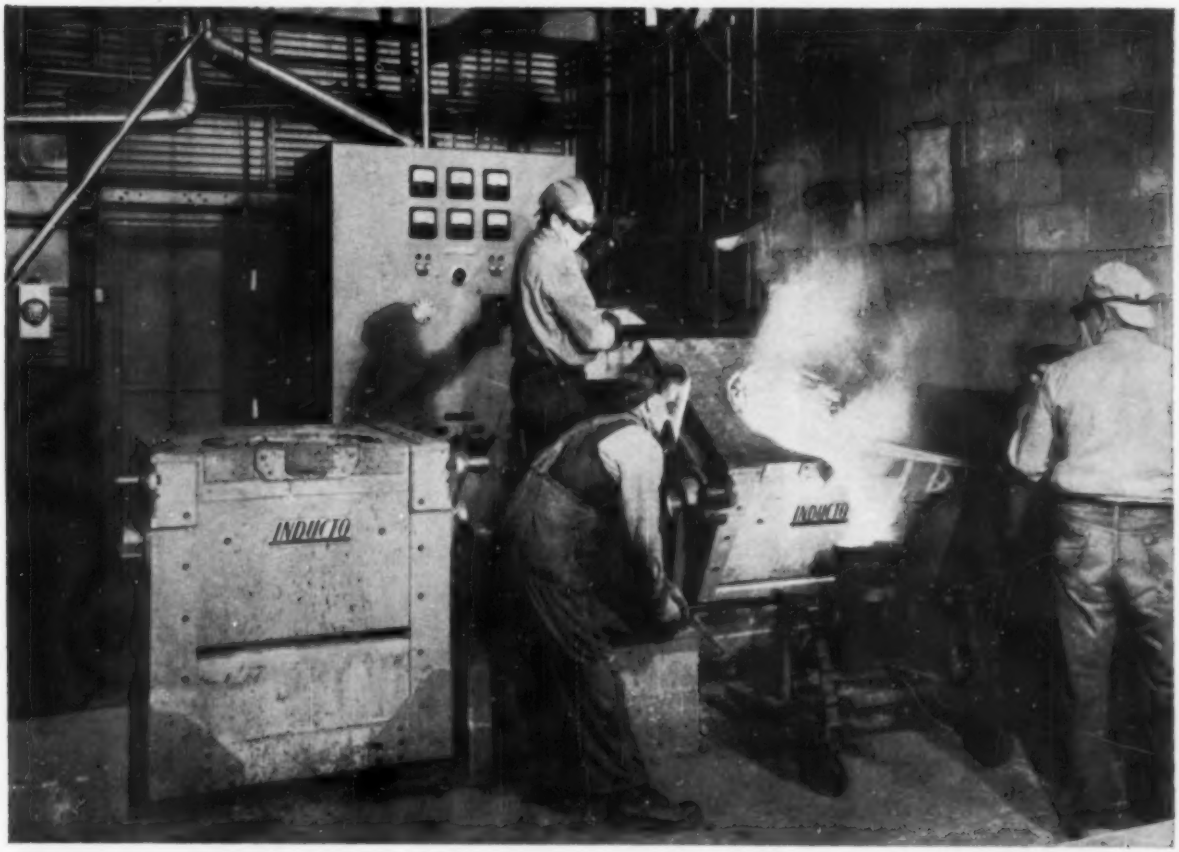
another Inducto installation...



Waukesha Improves Stainless Castings With INDUCTO Furnaces

Waukesha Foundry Company, Waukesha, Wisconsin, is a major producer of stainless steel castings with emphasis on parts for dairy and other food equipment. To minimize rejects, Waukesha has installed Inducto induction furnaces in its stainless foundry. If you are wondering how a furnace can cut rejects in castings, consider the following facts.

Inducto high-frequency induction furnaces with precision control provide a controllable analysis on alloys. Since the heat is generated in the metal itself, there is no excess or external heat to cause oxidation of some of the alloys. The electromagnetic stirring action of the induction furnace assures a uniform, homogenous alloy. Additionally, melt after melt can be exactly duplicated by the precise control of the Inducto equipment.

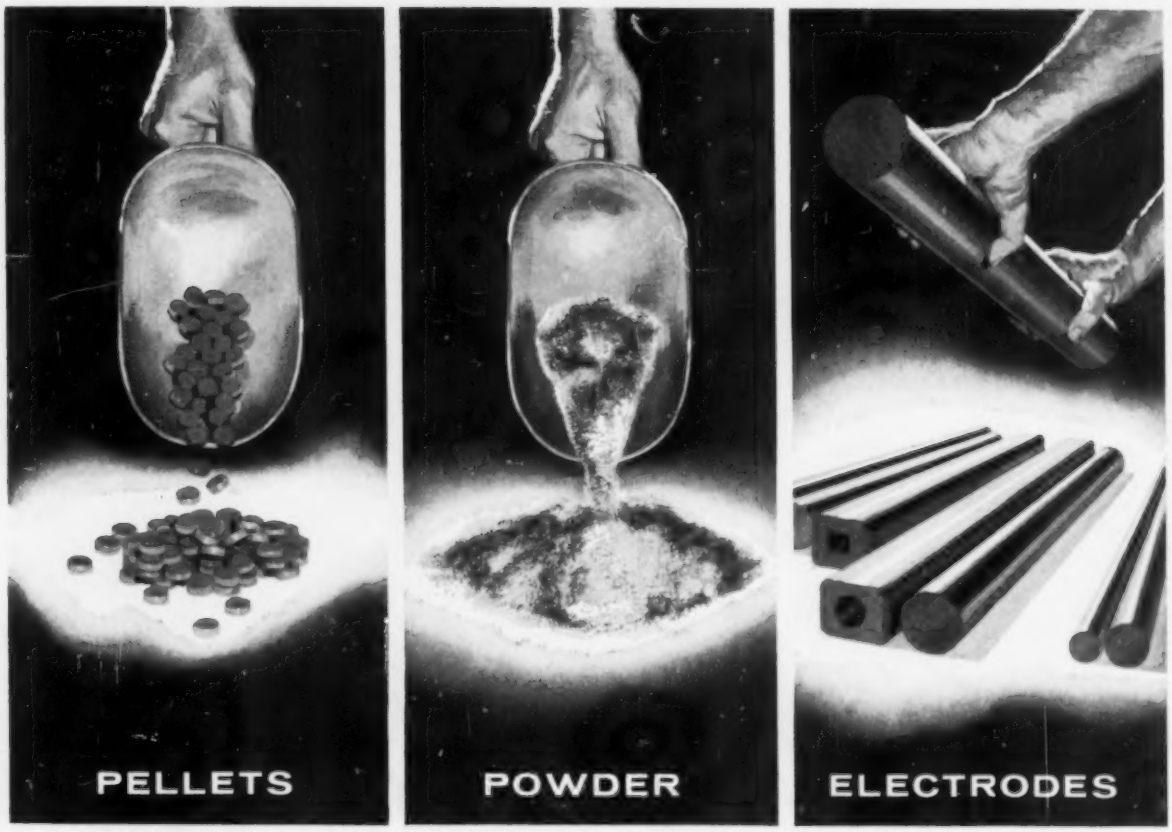
At Waukesha, two 650 lb. furnaces and an Inducto Push-Out furnace (not shown) are operated from a 175 KW m-g set and controlled from a single, compact control panel. The tilting furnaces are used for stainless castings while the Push-Out, a unique removable crucible furnace, is used for hard-to-melt non-ferrous alloys.

Design-wise, too, Inducto melting equipment offers many advantages. Learn how you can benefit from the use of the most modern melting equipment available today. Write to:

INDUCTOTHERM corporation

412 Illinois Avenue • Delanco, New Jersey

Sylvania Tungsten and Molybdenum



These valuable forms are producing practical solutions to important high-temperature problems

Powder for slip casting, pellets for vacuum melting, and consumable electrodes for arc castings. These are the important ways in which Sylvania Tungsten and Molybdenum are being used in the development of new and better high-temperature metals.

If any of these forms offer the right solution to your problem, Sylvania can supply the purity and composition you need.

Custom-made raw materials such as these help metals producers meet the precise demands of new high-temperature alloys. They are helping the industry make "Metals of the Future" available today.

You can keep pace with this continuing progress in powder metallurgy by contacting Sylvania's Chemical & Metallurgical Division. We will welcome the opportunity to discuss your high-temperature metal needs with you.

SYLVANIA

Sylvania Electric Products Inc.
Chemical & Metallurgical Div.
Towanda, Penna.

TUNGSTEN • MOLYBDENUM • CHEMICALS • PHOSPHORS • SEMICONDUCTORS

"...AND WEIRKOTE® CAN DO AWAY WITH PLATING OR DIPPING AFTER FABRICATION! IT WON'T PEEL OR FLAKE."

Q. A zinc-coated steel that won't peel or flake? That could save you a lot of money every month. Just what makes this Weirkote so special?

A. It's made by the continuous process, you know, which integrates zinc and steel so that the toughest fabrication won't break down the bond. You can work Weirkote to the very limits of the steel itself.

Q. Of course, that means the most complicated parts would have protection against rust. I like what I'm hearing. Is there more?

A. Yes . . . now Weirkote is treated to inhibit wet storage stain (white oxide). To make a long story short, I'd say this: With Weirkote, you can turn out a better product at lower cost. And you can free a lot of the capital, floor space and time you have tied up in plating operations.

Send for free booklet that details the time- and cost-saving advantages of skin-tight zinc-coated Weirkote. Weirton Steel Company, Dept. S-7, Weirton, West Virginia.

WEIRTON STEEL COMPANY

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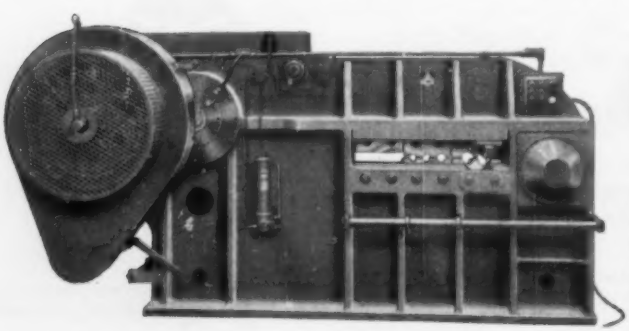
Production cutting of bar stock on a **HILL ACME** *Bar-Billet Shear with auxiliary automatic feed*

The nearest thing to automation achieved so far in the production cutting of bar stock is the HILL ACME BAR-BILLET shear with auxiliary automatic feed. With one man as standby observer, bars are fed automatically from the rack to the roll feed mechanism. Automatic stops on the billet shear predetermine the length of cut.

On ideal installations bars travel from steel storage on conveyors through the billet shear to tote boxes without being touched by hand.

HILL ACME BAR-BILLET shears have proven to be the most efficient, economical and trouble-free units on the market today. With the exclusive outboard support on the drop-off side, square, accurate cuts are assured. These high production shears are built in a variety of sizes to meet every cutting need up to 9" in rounds. A new bulletin covering all details of construction and operation is now available.



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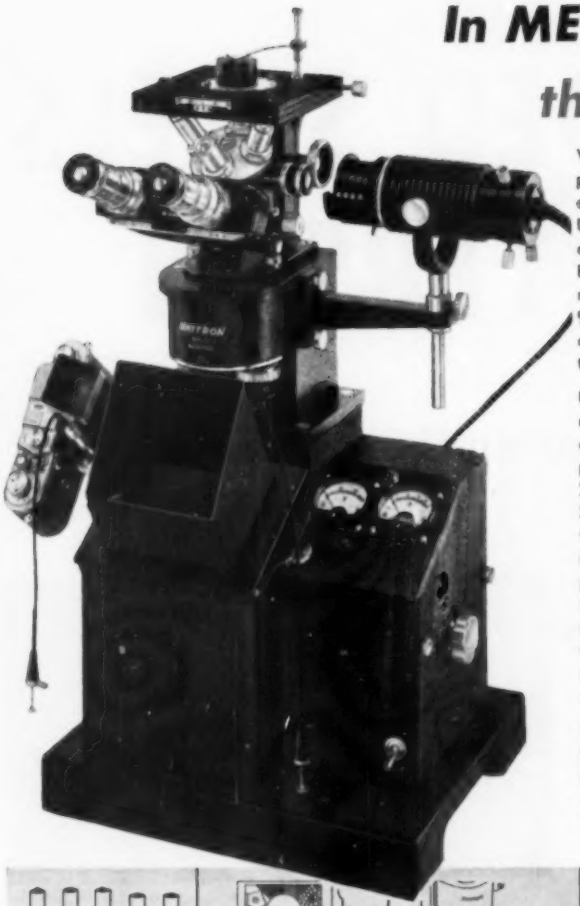
In METALLOGRAPHS...

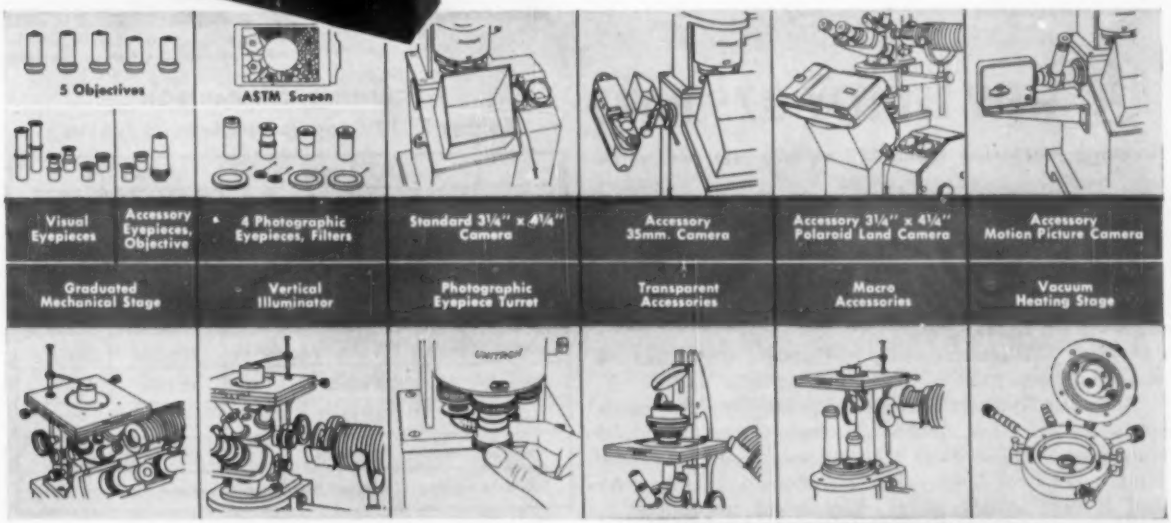
the trend is to UNITRON!



What do you look for when choosing a metallograph? All of the popular makes are precision instruments, are reasonably versatile and, to a varying degree, are easy to operate. But, except for UNITRON, all have the bulk of an office desk or optical bench and are tagged with a price that puts a substantial dent in the laboratory budget. UNITRON, and only UNITRON, offers a completely equipped metallograph in a compact and self-contained unit, taking only 9" x 12" of table space, which duplicates the performance of large cumbersome instruments — and at a price which is hardly more than the usual cost of a conventional metallurgical microscope.

Unlike the case with most metallographs, an adding machine is not required to compute its cost. Coated optics supplied as standard equipment include 5 objectives, 4 photographic eyepieces and 3 pairs of visual eyepieces. These give a magnification range of 25X-2000X. Also included in the purchase price are the built-in 3¼" x 4¼" camera and viewing screen; high-intensity illuminator for vertical, oblique, and transmitted light; variable transformer with both voltmeter and ammeter; accessories for transparent specimens; polarizing apparatus; filters; film holders; stage clips; cabinets etc. Optional extra accessories include Polaroid Land, 35mm. and movie camera attachments; low power (5X-40X) objectives for macro work; vacuum heating stage for temperatures to 1100°C and long working-distance 40X objective; ASTM Austenite grain size viewing screen and eyepieces; filar micrometer eyepiece; and additional optics.

Such a combination of features, versatility, convenience, and value is indeed unique with UNITRON. Little wonder then, that more and more laboratories are choosing UNITRON . . . from the large organization adding another metallograph to its equipment, to the small company buying an instrument for the first time.



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UNITRON's Metallograph and Universal Camera Microscope Model BU-11 with binocular eyepiece; objectives: M5X, M10X, M40X, 40X for transmitted light, 100X oil immersion; paired visual eyepieces: R5X, Ke10X Micrometer, Ke15X; photo eyepieces: 10X, 15X, 20X, Micrometer; etc., as described above.

$1379 f.o.b. Boston

Monocular Model U-11 **$1195**

THE TREND IS TO UNITRON

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INSTRUMENT DIVISION OF UNITED SCIENTIFIC CO.
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NEW LEADED STEELS FROM RYERSON

Now, machine parts faster than ever before

NEW LEDLOY 170 TUBING

average machining speed 170 surface feet per minute

Here's the fastest-machining steel tubing ever produced —and only Ryerson has it available for immediate shipment from stock. Ledloy® 170 is a cold drawn, seamless product of low carbon analysis with .15% to .35% lead added. It promises a minimum increase of 25% in productivity of machined parts or components. Sizes range from 1" to 2½" O.D. with maximum ⅜" wall thickness. Other sizes can be supplied promptly.

Part produced from Ledloy 170 Tubing for machining-comparison at National Metal Show.

NEW LEDLOY 375 BARS

average machining speed 375 surface feet per minute

This newest addition to Ryerson free-machining screw steel stocks is the world's fastest-machining steel. Assigning the figure 100 to B-1112 and using this as a base, Ledloy 375 has a machinability index of 205 plus. It rates about 64% higher than B-1113 and about 20% higher than Ledloy 300.

Ledloy 375 bars presently in Ryerson stocks include rounds in sizes from ¼" to 1", hexagons ¼" to ⅝".

Ask your Ryerson representative for complete details on these new steels. And call Ryerson for an unequaled selection of cold finished bars and tubing, including the largest stocks of Ledloy 300 (also known as Ledloy A) and Rycut® leaded alloys—the fastest machining in their carbon ranges.

MACHINING COMPARISON*
Ledloy 170 Tubing vs. Nonleaded Tubing

	Ledloy 170		MT-1015	
	Speeds	Feeds	Speeds	Feeds
Center drill	172 s.f.m.	.005"	110 s.f.m.	.005"
Form tool	172 s.f.m.	.0008"	110 s.f.m.	.0008"
Boring tool	172 s.f.m.	.007"	110 s.f.m.	.007"
Cutoff	172 s.f.m.	.0013"	110 s.f.m.	.0013"
Thread	27 s.f.m.	—	20 s.f.m.	—
Tap	18 s.f.m.	—	12 s.f.m.	—
Production time	35 seconds		49 seconds	

* As demonstrated at National Metal Show, Cleveland, 1958.

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Metal Progress
Volume 74, No. 6 December 1958

Critical Points

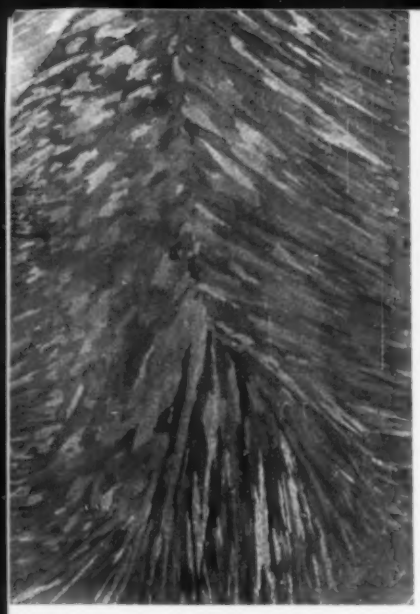
Homogeneous Steel

To Pittsburgh – Churchill Borough, rather – to visit my old friend Howard Scott, chief metallurgist of Westinghouse's Research Laboratories, and spend a day discussing steel quality – especially in the immense forgings now used in electrical generating equipment. While his firm has avoided any of the unfortunate and disastrous generator failures during the last few years, some rotors have had to be replaced at no little expense because creep under operating stresses changed their dimensions enough to cause interference at necessary clearances. Likewise there is an insistent demand from designers for turbine rotors which can operate safely when the maximum rotor temperature exceeds 950° F., or for generator rotors which will withstand fracture at the higher centrifugal stresses at quite moderate temperatures.

Although you confine your attention to a single steel analysis (0.30 C, 0.60 Mn, 0.20 Si, 2.75 Ni, 0.50 Mo, 0.10 V, one of those long used for large forgings), there are a multitude of manufacturing variables which influence the many metallurgical variables which in turn influence the several physical and mechanical tests which may or may not be closely related to the critical criteria for design and safe operation, and Scott says that important leads were discovered in the metallurgical literature which at first glance had small relationship to the problem. For example, uniform extension in a tensile test piece seems more significant than equivalent elongation in another quality of steel which necks more sharply at fracture. Thus, more information is needed than the conventional ductility percentages.

The reader must always bear in mind that the forgings under scrutiny are very massive, weighing tons, and therefore of such size that the many expedients available for small parts which can be rapidly quenched are unavailable. The optimum microstructure of strong steel – tempered martensite – cannot be produced; the best that can be achieved is a uniform distribution of fine-grained bainite with minimum ferrite in the matrix. Even that is far from easy.

During the forging operations, these large ingots are above 2200° F. for at least 48 hr., so there is opportunity for substantial homogenization. Such treatments must be simulated in the laboratory to obtain consistent and meaningful test re-



Left – Cast in water cooled copper mold slightly tapered; big end down; dished copper base containing a few steel chips for starting arc

Center – Cast in water cooled copper mold, not tapered, flat copper base with a central steel starting plug inserted

Right – Cast in water cooled copper mold, not tapered, steel base into which the ingot was fused, and through which the molten steel was vibrated ultrasonically until completely solidified

Diametral Cross Sections of Bottom Portions of 12-In. Round Ingots, 6 Ft. Long, Etched With Ammonium Persulphate to Show Dendritic Crystals. These ingots were made by vacuum arc casting of 8-in. electrodes of Ni-Mo-V forging analysis, basic electric steel, vacuum poured. Electrical, vacuum and other metallurgical conditions as close in all three as practically possible

sults. Subsequent heat treatments must also be selected to avoid excessive grain growth. Furthermore, a substantial gain in creep ductility results from grain refinement of turbo rotor steel even though some loss in creep-rupture strength is incurred. Advantage is now being taken of this fact to improve the performance.

From among the many other important considerations which cannot be discussed in a short "Critical Point" (not least of which is improved chemical analyses), the Editor's appraisal is that the final steel must be as nearly isotropic as possible. Inherent in that statement is the idea that the steel must certainly have no internal defects and be as free as possible of inclusions and stress-raisers. This means clean steel, *very* low in solid or gaseous impurities, and with a minimum segregation of constituents along dendritic boundaries – cast *without* dendrites, if such be possible. Fortunately for this investigation, Westinghouse has its own metallurgical pilot plant with vacuum melting furnaces at Blairsville, and enjoyed the full cooperation of United States Steel Corp. and Universal-Cyclops Steel Corp. possessing larger equipment.

First, an 80-ton heat of basic electric steel for a generator rotor was made at Duquesne Works by double-slag process which drives the sulphur and phosphorus to less than 0.015% each. This heat was then vacuum cast to reduce the hydrogen to less than 1 ppm., and forged into a rotor blank. Bottom stock taken from this blank was then forged into eight electrodes, 8 in. diameter, 15 ft. long, for arc casting experiments. Although this is undoubtedly a high-quality heat, it still retained some oxygen, which like sulphur is particularly detrimental to transverse ductility. A basic question is: How much can transverse ductility be improved by removing the oxygen retained in the heat?

This was done by arc casting in vacuum. The furnace is a tall evacuated cylinder, high enough to hold a 12-in. water cooled mold, 7 ft. long, and the 15-ft. bar (electrode), which melts drop by drop and transfers through the arc to a molten puddle of steel in the mold below. While the steel is molten, there is ample time and chance for the carbon to reduce the oxide, and the oxygen or carbon oxides to be sucked out of the melt by the vacuum pumps. This process forms an ingot 12 in. in diameter and 6 ft. long. It should be quite free from impurities and stress-raisers, but on sectioning and etching very pronounced columnar crystallization was discovered, a matter

which was not corrected by double melting (repeating the process) even into a larger 16-in. mold. This of course would mean banded structure and directional properties in the forging, caused by segregation of the alloying elements.

Then came the inspiration: Crystallization could not be nucleated by inclusions (that introduces stress-raisers). Why not break up the growing crystals mechanically by shaking the mold? That scheme had been tried decades ago and discarded as worthless. But why not do it in the modern way – ultrasonically?

So a large ultrasonic transducer was built and put into the vacuum furnace. On it was put a steel stool and the first arc-deposited metal welded into it. The transducer then vibrated the molten metal, not the mold.

It worked! Such an ingot has small equiaxed crystals!

Missile Testing

The Army Ordnance Association recently held a meeting at White Sands Missile Range, some 50 miles north of El Paso, and judging from the attendance one would guess that half the companies listed on the New York Stock Exchange are making items for these complicated projectiles! Of course some of them aren't so complicated; I suppose a bazooka is a missile in the same sense that the "Honest John" is merely a warhead thrown by a rocket rather than by exploding gunpowder and is therefore a substitute for long-range artillery. At the other extreme of complexity is the intercontinental ballistic missile called the "Atlas" which travels at Mach 15, whose early flight is controlled by radio commands and then an astronomical system takes over to guide it to its target. Whether or not this will make the jet bombers of the Strategic Air Command obsolete depends upon opinion. A friend in the Air Force took pains to point out that an Atlas costs about as much as a B-36 (the Strategic Air Command's work horse) and it can't come back.

White Sands is only one of several busy sites operated in southern New Mexico near El Paso by the Defense Department, and all of them together have changed that quiet border town into a brassy neon-lit center of 275,000 people in little more than a generation. However, the same sun blazes down through cloudless skies and the same Mexicans gossip on the benches around the plaza. Near El Paso is Biggs Air Force Base, one of 59 of the world-wide Strategic Air Command, one-third of whose aircraft are armed and either in the air or ready to fly within 15 min. There is Fort Bliss, once for cavalry, but now given over to training soldiers for the Nike fortresses surrounding many American cities, and also there is McGregor Range, where squadrons are given "refresher" courses by actually firing the missiles at flying targets.

White Sands Missile Range, even though under Army command, is a joint proving ground for Army, Navy and Air Forces. A missile is a missile, no matter how launched, and requires the same general types of tracking and command equipment. Only those of relatively short range can be tested here, for the area is but 100 miles long by 40 miles wide; in fact the 100 miles is even now too short for comfort. About 10,000 people (more than half of them civilians) are employed. Numerous laboratories are available to the services or any of their contractors to make all manner of tests on components or subassemblies. One unique building houses an instrument "library," where millions of dollars' worth of scientific equipment are available for short loan.

Civilian firms are nearly always responsible for the design and construction of missiles – for example, Western Electric and Bell Telephone Laboratories the three Nikes. Once the design details are approved and the assemblies completed, a lengthy series of tests, running up to 500 in number, is necessary to prove its acceptability under all conditions of operation. In an actual firing test, dozens of observation stations down-range simultaneously track the missile optically, by radar or radio, and by sound (pressure) waves. Coordination of this mass of information and its translation into performance data are correspondingly complicated. We were told that a computer system is being perfected which can solve an equation relating the six degrees of freedom and thus predict the flight pattern, and it is hoped that this will cut the number of required tests to nearer 50.

Even after a missile like the Honest John is in production, acceptance tests are made on regular schedule. Individual parts are selected at random from production lots and assembled into missiles at the Range, and then fired under full scrutiny. The people at White Sands are confident that one of their great advantages is that the target is always under observation and a misfire can be recovered and the reason for malfunction often determined.

Those attending the meeting watched the firing of several missiles at targets far too distant to see even with good binoculars, and were told that each target was hit. Since we were assured that the anti-aircraft projectiles were fast enough to catch up with any piloted aircraft now flying, one should be assured that our defenses are strong. But one views with mixed feelings all this show of power and the rate at which it is proliferated. Remember World War I (the war to end war)? At its beginning the airplane, made of wood, fabric and wire, flew at about 100 miles an hour and was good only for observation. World War II, 25 years later, saw the all-metal bombers and fighters at 250 miles per hour, and (at its end) the birth of the jet engine. By 1965 (another generation later) we can expect Mach 2.5 fighter-bombers of titanium or stainless steels and Mach 15 homing missiles!

Meanwhile the power of explosives has increased a million fold. These developments are absorbing an increasing proportion of our resources and scarce brain power. Where can it end? Diplomacy is as a turtle to technology's race horse. By the time the ambassadors can agree on any plan to avoid dangerous emergencies, they are talking about past history, for the scientists and engineers have created an entirely new environment.

The soldiers, sailors and flyers in the El Paso region are optimistic, and apparently feel that we are so much more than a match for the Russians that they dare not start anything. I hope the Russians agree, and do not send any Sputniks our way. However, we are in an arms race, at least as far as missiles are concerned, and did any arms race ever end in anything but war? God save us from the madman who pushes the button!

Design Allowables in Weldments

The Editor thoroughly enjoys the annual meetings of the Atomic Energy Commission's Welding Committee, for Frank Davis, the chairman, always presents important topics to discuss and a first-class group of engineers discusses them with no holds barred. The recent meeting at Richland, Wash., was no exception. At one session the problem of "design allowables" was on the table and two sides took strong but divergent stands. In these comments there is no need to identify the disputants or even the alloy.

Sufficient to say that on one side was an important consumer of top-quality weldments and on the other were representatives of a large contracting shop who received strong support from the producers of the metal. This can be identified as an age hardenable alloy long and widely used for high-grade items. A large amount of data has been published about its physical properties in various conditions. Reported results are quite consistent and recognized as such by various specifications and codes. Let us say that the expected tensile strength of butt welds in half inch plate after specified heat treatment is S psi. This would be the proper "design allowable" (in the view of mill metallurgists and welding engineers) and the designer should divide this by a chosen factor of safety and the vendor and purchaser should check the integrity of the joints by proper inspection during manufacture and after receipt.

Now comes an important consumer who is dismayed at the variable results of tests performed in a quality control program, and finally came to the conclusion that either the accepted design allowables are too high, or that even the most stringent radiographic, penetrant and visual inspection cannot spot a quite deficient joint. To check this tentative conclusion he designed something called a spacer on the blue print, made up of four different thicknesses of plate and sheet joined with butt and lap welds. Plates were bought under competitive bidding from each of eight contracting shops, it being specified that the pieces should be heat treated according to code. Half of the shops were asked to furnish the parts to Class I-A inspection (highest quality) and the other half of the shops to Class II-B (visual) inspection. The consumer's own shop made similar "spacers." On delivery the "spacers" were cut into conventional test pieces and several hundred tensile tests made and tabulated. When these results were plotted by categories of strength, as would be done to determine a probability curve, the diagram showed that the processes were completely out of control. When an arithmetic average was taken, the tensile strength of these heat treated butt welds (Class I-A and Class II-B as a group) came out as 0.6 S psi. The investigating firm now proposes to use 0.6 S instead of 1.0 S as the "design allowable" of butt welded, heat treated parts, and justifies the averaging of high values with low on the basis that a single seam may have weak spots, but alongside there will be enough strong weld to support the below-par portions.

"No, no", cry the metal men, "don't degrade this good alloy!" "Dirty pool", say the venders, "why didn't you say you were buying test pieces rather than spacers?" "Don't penalize the whole welding industry for the sins of a few careless shops!" "What's the matter with your inspection?" is another rejoinder; "You should have been able to throw out the bad samples and not mix the good with the bad." About all that received acceptance of everyone was that hand welding is more variable than machine welding, and that the very best guarantee of high-grade work is close and expert supervision by foremen on the job as it is being done.

A heartening result was the appointment of a small committee with Alcoa's G. O. Hoglund as chairman to dig further into this very important problem. If the Editor may be permitted a guess, it would be that this group will find that the published and unpublished tests on which the higher design allowables are based are heavily weighted with laboratory work done under practically ideal conditions, or joints made by the highest grade of shopmen who knew (or guessed) that they were welding a test piece. In the meantime I can imagine times and places where it would be better to put a bit more metal into a part and get the part into service than to refine the design and wait for replacements of rejects. Average shop production is what the consumer really gets. In weldments the quality is also likely to be much more variable than a wrought product which gets all sorts of proof testing under the forge or in the rolling mill.

Rolling Sheet in Kokomo

SUPERALLOYS, because of their built-in toughness at high temperatures, are extremely difficult to forge. Rolling – particularly into the thin sheets prized for jet aircraft skins – is even more of a problem. Alloys such as these are still tough within the necessarily narrow hot working range; this deficiency is compounded by the natural tendency for sheets to cool rapidly to below this range and become immovable. There's the rub: How do you get the sheets from furnace through rolls before they become too cold to deform? It isn't easy, but it can be done. In fact, it is being done daily at the Haynes Stellite plant in Kokomo, Ind. Engineers and metallurgists have evolved some unique equipment which enables them to roll superalloy sheet almost as a routine.

To the eye, it looks quite simple. Hastelloy ingots, which may vary in length but are no more than 5 in. thick, travel from the furnace at 2200° F. to the three-high roughing mill. Rolling to plate is rapid; there is no delay for roll reversal in the strongly built mill since the rolls never change direction. Instead, the run-out table lifts to return the plate between the center and the top rolls after it is compressed between bottom and center. This continues back and forth until the plate is ⅜ in. thick.

Air cooling, pickling and conditioning follow, after which the plates are conveyed to a specially built roller hearth. Among the features of this furnace are the hearth rolls which carry the plate; they are individually water cooled since they must withstand 2150° F. The critical exit rolls are covered with Hastelloy alloy. As a plate travels to the end of the hearth, it gradually heats to the rolling temperature. When hot enough, it speeds to the nearby two-high mill. This finishing stand is termed a "jump" mill – its bottom roll is driven, the top roll rests on it, and the space between the two is closely controlled by an adjustable screw on the bearings. Sheets down to 0.050 in. thick can be rolled by this mill. An additional feature is that each roll is continuously ground automatically so that the sheet will have a scratch-free surface. After the finished sheet is inspected, it is ready for shipment.

As a sidelight – and to give the designers a pat on the back – it might be mentioned that the major problem encountered during operation concerned the water cooled hearth rolls of the furnace feeding the finishing mill. The salts in the hard water available for cooling at the Kokomo plant site settled on the inside and gradually closed the bore. Consequently, periodic cleaning was necessary. Recirculated city water is now used; trouble still occurs but nowhere near as much as before. Otherwise, the equipment, which was designed for maximum rigidity and strength, operated as expected.

This superalloy sheet mill has been going for several years now. Its continuing success will undoubtedly be of great aid in the development of faster jets and missiles so much in demand today. Even now, new Sendzimir mills at Kokomo roll high-temperature alloys to the foil thickness needed in high-temperature sandwich structures for high-speed flight. C.R.W.

Fig. 1 — Test Bars Produced From New Alloy Iron Powder, Shown Before and After Stretching, Illustrate Ductility Characteristics. Parts in background are typical components for automotive, appliance and hardware applications for which the low-alloy powder would be suitable

What Carbon and Alloys Do for Iron Powder

*By S. R. CROOKS**

New uses for powder metallurgy parts in structural applications subject to high loadings promise to be opened up by iron powder containing alloy and carbon additions. Powders are soft and easy to briquet; parts develop high strength with short sintering time and simple heat treatment. (H12n, H-general; Fe-a, ST)

WHEN WE SURVEYED fabricators of powder metallurgy parts in 1954 to determine their requirements for a better iron powder, our findings were discouraging. The concensus was that if powders are developed to extend the powder metallurgy horizon they must satisfy these criteria:

- Parts must have a high tensile strength (above 60,000 psi.) and be about equivalent to carbon steel.
- A low dimensional change (less than 0.004 in. per in.) is necessary, so that distortion can be minimized, and tool design simplified.
- Standard sintering, pressing and processing techniques must be applicable so that it would not be necessary to develop an entirely new set of skills.
- Powder should be soft to minimize tool wear and to make it easy to get high densities and high strengths.
- Higher elongation than provided by conventionally made parts is necessary. (The elongation properties of a porous part are, of course, considerably less than those of a fully dense material. However, it was felt that the ductility must be raised above the 1 to 2% attained with available powders.)
- The use of the powder should be economical to compete with present powdered metal or other methods of production.
- The powder should be reproducible and its performance reliable.

This was a formidable order, but after several years of work, we have successfully developed a low-alloy iron powder which satisfies all the above requirements.

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The new powder can be sintered and heat treated to give parts in which tensile strength reaches 190,000 psi. When sintered in hydrogen, without carbon additions, parts are produced having an elongation of 23% with a tensile strength of 42,000 psi. When re-pressed and sintered with carbon, the material will yield a tensile strength of 75,000 psi. with elongation of 7 to 8%. The dimensional changes accompanying these values are less than 0.4%. The handling techniques are those in common use throughout the industry; briquetting pressures, sintering temperatures and times, and heat treatments are according to accepted practice. We believe the powder will fill a need, particularly in the essential area of structural parts.

Although powder has been used for making parts for years, its early promise – the potential extension to a wide variety of parts and applications – has not been fulfilled. One reason: The mechanics of powder compaction impose certain limits on the size of the finished article. Certainly, the size of the press is an important limiting factor.

However, there is the feeling among fabricators that inadequacy of the powders themselves, rather than the limiting of presses, is largely responsible for the slow growth of the powdered parts industry. Over the years this led to a great deal of developmental work, and the quality of iron powder and of nonferrous powders has been greatly improved.

But many basic problems remained. Parts made with copper mixes or by infiltration, for example, still are limited in physical properties, even though these limits have been extended upward so that they approach the lower ranges of wrought materials. A combination of copper and graphite with iron powder gives compacts with fairly high strength, but inherent brittleness has restricted the use of this mixture.

European Practices

Other limitations on application of powder metallurgy to high-strength structural parts are those imposed by sintering temperature and time. European fabricators often use higher temperatures (2200 to 2500° F.) and furnace times may frequently be extended to as much as 3 hr. These treatments give parts having a density and performance which approach that of wrought materials.

High temperature and long furnace time, however, have not been acceptable to American industry, where high production rates are considered essential for economic reasons. Long sintering time reduces the furnace capacity, which negates in large part the benefits of high-volume operation associated with powder metallurgy. Capital costs for such furnace installations are considerably higher than for conventional powder metallurgy installations.

Thus, the hoped-for invasion of the field for small, moderate and high-strength structural

New Horizons for Powder Metallurgy

Design engineers and metallurgists should take a fresh approach to possibilities of using powder metallurgy parts in structural applications. A new low-alloy iron powder offers these properties:

1. Tensile strength of 60,000 psi. min. at a sintered density of 6.4 g. per cc., when used with carbon.

2. Tensile strength of 110,000 psi. min. at 6.5 sintered density, when heat treated.

3. Shrinkage of less than 0.005 in. per in., at density above 6.4 g. per cc., either as sintered or heat treated.

4. Tensile elongation of 6 to 8%, in as-sintered condition, after annealing and re-pressing. This ductility is accompanied by a strength of at least 75,000 psi.

5. Tensile elongation of 20% or more, at tensile strength of 45,000 psi. for re-pressed bars without carbon addition.

6. Tensile strength of 180,000 to 190,000 psi., in heat treated condition, after annealing, repressing and sintering. Elongation is 1.5%.

7. A tensile strength of 100,000 psi. with 4% elongation for a compact which has been annealed, re-pressed, sintered, heat treated and then drawn at 1200° F.

8. Powder is easily briquetable and has high strength. Properties above are developed with short sintering time at conventional temperatures. Simple heat treatment gives high strength.

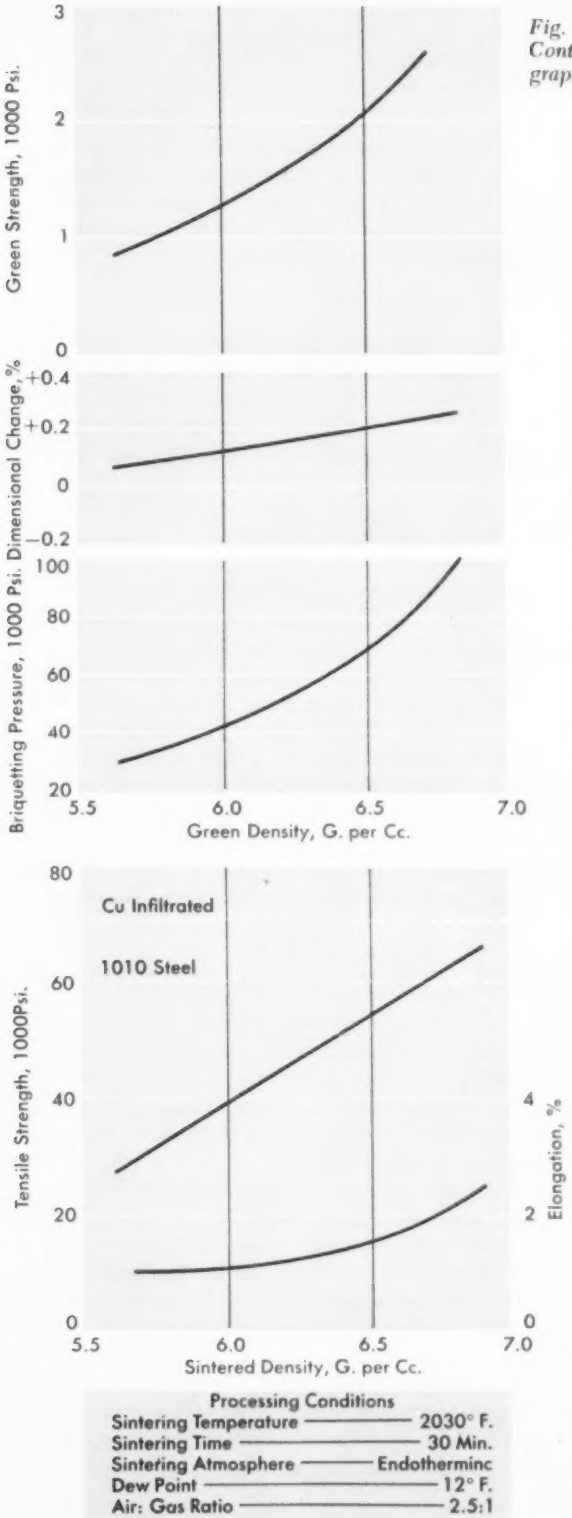


Fig. 2 – Properties of Iron Powder Containing Carbon. Additions: 1% graphite; 1% lubricant (zinc stearate)

parts by powder metallurgy has not taken place. The industry has had to be content with a slow, although steady, growth as applications have opened up within the limited area of strength and performance.

It was against this background in the early 1950's that metallurgists at Republic began a serious examination of an idea which had often been expressed in metallurgical circles: The future of iron powder metallurgy lay in the direction already taken by steel, where carbon is the main additive, and where properties desired for a finished product or part are achieved by heat treatment.

The survey, already discussed, was then made to establish the parameters more clearly. A program got under way to develop a powder which would give the desired properties when sintered with carbon alone. The first step was the selection of a proper raw material. The source selected was roll scale from our rolling facilities.

Iron Powder Plus Carbon

Data in Fig. 1 show the general behavior of iron powder when sintered with graphite. It can be seen that tensile strength varies from 40,000 to 65,000 psi., depending upon whether the part has been made at high or low pressure.

This strength range is close to that of carbon steel and is better than that of sintered iron-copper powder mixtures. However, the strength is still somewhat below that of copper-graphite-iron compacts, but it does not give the brittleness of these mixtures. Another point: While the tensile strength is less than that of an infiltrated piece, the cost of manufacture is substantially below the cost of infiltration with its double sintering.

A major advantage shown by this graphite-iron mixture is the nearly zero dimensional change. This means that tools can be designed essentially to blueprint dimensions, rather than requiring allowance for the sometimes erratic growth exhibited by copper additions. The powder is as soft as those generally available. The sintering atmosphere may be either scrubbed, exothermic gas or cracked natural gas. The dew point of either gas must be held at the proper level to maintain the desired final carbon content. This practice is the same as for steel,

Fig. 3 – Properties of Low-Alloy Iron Powder. Alloying elements 2% Ni, 0.5% Mo, and 0.3% Mn. Additions: 1% graphite and 1% lubricant (zinc stearate)

where precautions must be taken to avoid oxidation or decarburization during treatments.

Where strength is an important criterion, however, it was evident that the strength ceiling on this powder was definitely limited, even though the ease of reaching the ceiling had been improved. With conventional steel practice still our guiding concept, we turned to alloys. The goal was to find methods of incorporating alloying agents into iron powder to raise the strength ceiling above the existing level, without going outside the limits of economics or processing practices acceptable to the industry.

Alloy Powders

Two basic approaches were open: first, the use of a pre-alloyed material, which by atomization and proper treatment could be made into a powder. Second, the alloy could be formed during the manufacture of the powder. The latter procedure was inherently more difficult, because no melting occurs, and solid-state diffusion alone would control the quality and extent of alloying. The field of atomization and treatment of pre-alloyed powder had already been explored widely. For this and other reasons, we decided upon the second method for trial.

Early in our work, we found that high strengths could be achieved using alloying elements such as nickel, cobalt, molybdenum and tungsten with iron. Unfortunately, high strength was also accompanied by shrinkage, which was completely outside a reasonable range. The investigation then narrowed down to finding alloying elements which would retain the high strength, but reduce dimensional change to acceptable levels.

After extensive work, we decided on iron powder containing 2% Ni, 0.5% Mo and 0.3% Mn. After thorough testing at the pilot-plant level, we moved up to production lots. The alloying elements are added during final steps of processing the iron powder. The properties of the alloy powder in simple pressing and sintering are shown in Fig. 2. These values were derived from M.P.I.F. (formerly M.P.A.) tensile bars which were pressed over a range of pressures and then sintered in endothermic gas for 30 min. at 2030° F.

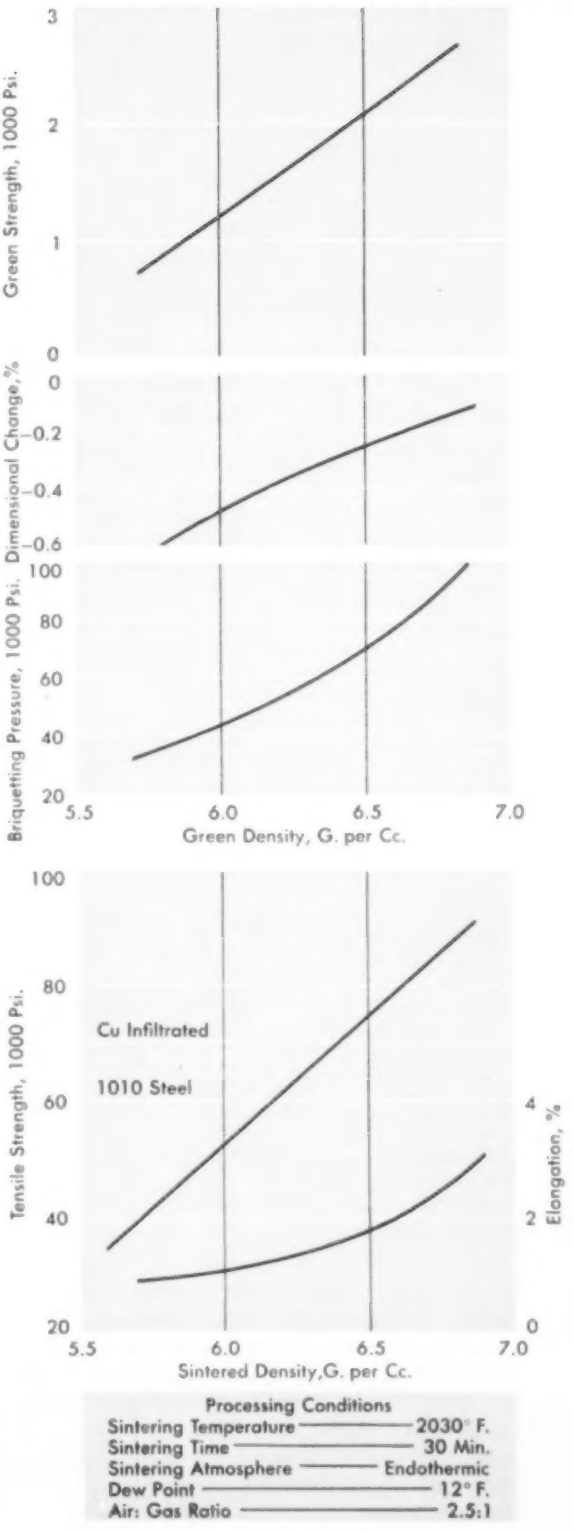


Table I – Typical Properties for Heat Treated* Parts Made From Alloy Iron Powder Containing 0.6% Carbon

Briquetting Pressure	Sintered Density	Tensile Strength	Dimensional Change
60,000 psi.	6.4 g. per cc.	110,000 psi.	−0.4%
80,000	6.6	125,000	−0.3
100,000	6.8	140,000	−0.2
120,000	6.9	152,000	−0.18

*Heat treating procedure: Soak for 10 to 15 min. at 1600° F., oil quench at 135° F., draw at 500° F. for 30 min.

Table II – Properties of Re-Pressed Sintered Parts Made From Iron Alloy Powder

Carbon addition	—	0.4%
Sintered density, g. per cc.	7.4	7.38
Elongation	22%	8%
Tensile strength, psi.	45,000	75,000
Dimensional change	−0.10%	−0.35%
Atmosphere	hydrogen	endothermic

Processing conditions:
Briquetting pressure, 40 tons per in.
Re-press pressure, 40 tons per in.
Annealing temperature, 1275° F.
Sintering temperature, 2030° F.
Sintering time, 30 min.
Atmosphere, endothermic gas with 2.5:1 air:gas ratio. Dew point adjusted for 0.4% C by electrodryer.

Table III – Properties of Re-Pressed Heat Treated Parts Made From Iron Alloy Powder

Carbon addition	0.4%	0.6%	0.4%
Draw temperature	350° F.	500° F.	1200° F.
Sintered density, g. per cc.	7.30	7.27	7.30
Elongation	1.5%	1.5%	5.5%
Tensile strength, psi.	190,000	187,000	95,000
Dimensional Change	−0.34%	−0.45%	−0.50%

Processing conditions
Briquetting pressure, 40 tons per in.
Re-press pressure, 50 tons per in.
Annealing temperature, 1275° F.
Sintering temperature, 2030° F.
Sintering time, 30 min.
Atmosphere, endothermic gas, 2.5:1 air:gas ratio. 24° F. dew point.

The curve relating tensile strength to sintered density shows that the simple press-sinter operation gives strength values equal to or above copper infiltrated parts, unless infiltrated parts are carefully heat treated and processed. Dimensional change curve shows that the shrinkage is within the limits laid down by fabricators when the density goes above 6.3 g. per cc.

Green strength is comparable to ordinary iron powders; parts made from the alloy powder can be handled in the same way as other iron powder parts. Study of the curve on briquetability reveals that the alloy powder is easily pressed and has a favorable pressure-density curve. This means tool wear is in line with conventional powders and design of dies can follow established patterns. The elongation properties are not unusually high, but the density of the compacts is markedly less than that of a wrought article – from 80 to 90% of full density.

The values in Table I are representative of a heat treating cycle which consists of soaking for 10 to 15 min. at 1600° F., quenching in oil at 135° F., and drawing at 500° F. for 30 min. This procedure has been found to be about optimum for the alloy powder, although small variations in tempering and soaking temperatures are not significant. The strength values shown in Table I are accompanied by relatively low elongation values – in the range of 1 to 3%. Apparent hardness values are Rockwell C-35 to 40, although microhardness values are considerably higher, approaching C-50 to 60.

While the mechanical properties given in Table I show a higher strength than is normally obtained in parts made from powder, the properties are still those of a porous material. Since the physical properties of a compact, generally, are directly related to its density, higher densities should give increased strength. However, because of tool and press limitations, and also because the briquetting pressure is an exponential function of the density, higher pressures were discounted as a route to higher densities. An annealing-repressing cycle instead was employed for reaching the higher values.

Improved Properties

A new field in powder metallurgy is revealed by the values shown in Table II. A pioneer in this industry once said that the strength of 1010 steel with 10% elongation would open up a vast number of new applications for powdered metal. The data in Table II describe such a powder; in addition to the strength and ductility, the shrinkage is within limits. The simple press-repress cycle adds somewhat to the cost of making parts. The annealing step prior to re-pressing is accomplished at 1275° F. (to avoid any possible formation of austenite) and re-pressing is done in the same die

or one identical to the briquetting die. Sintering is performed as it is now done within most plants at 2030 to 2050° F. for 30 min. in an endothermic atmosphere.

It is believed that broader consideration in engineering design can be given to parts with properties shown in Table III than previously possible. Strength properties are high, shrinkages are low and processing steps are relatively simple when compared to operations required to reach the same values by other means.

Heat treatment of re-pressed pieces is done by soaking at 1550 to 1625° F. (depending on the carbon content) for 10 to 15 min. They are then quenched in oil at 130 to 140° F., and drawn at 350 to 1200° F. Low-temperature draws give compacts with high strength and hardness, while high-temperature draws yield lower strength with higher ductility. Full-scale testing to evaluate fatigue strength and impact properties is now under way. The available data indicate that the endurance ratio will exceed 0.4 for compacts which have been pressed, sintered, and heat treated with density of about 6.6 g. per cc. As yet we do not know what the fatigue properties will be at higher densities of re-pressed bars, but it is felt that the endurance ratio will approach that of fully dense materials. Up to now we have only studied impact strength for the lower density compacts. Here the results obtained were well below those of conventional steels, but it is believed that the higher density parts made by re-pressing will give impact properties which will approach standard materials.

Background for Research

During studies which led to the development of our alloy powders, we found it necessary to depart from accepted thinking. Initial work was aimed at complete alloying of the elements which were added to the iron powder. However, further work revealed that when complete alloying was attained by our method high shrinkage values were reached.

It appeared that the character and extent of diffusion were the controlling factors in dimensional change upon sintering. Work was then done to find the relationships between diffusion and shrinkage and diffusion and strength. It was found that by limiting the degree of diffusion to an optimum level the high strength properties of the alloy powder were retained, and shrinkage was not a problem. This condition is illustrated in the photomicrograph shown in Fig. 4, where it is apparent that alloying is far from complete.

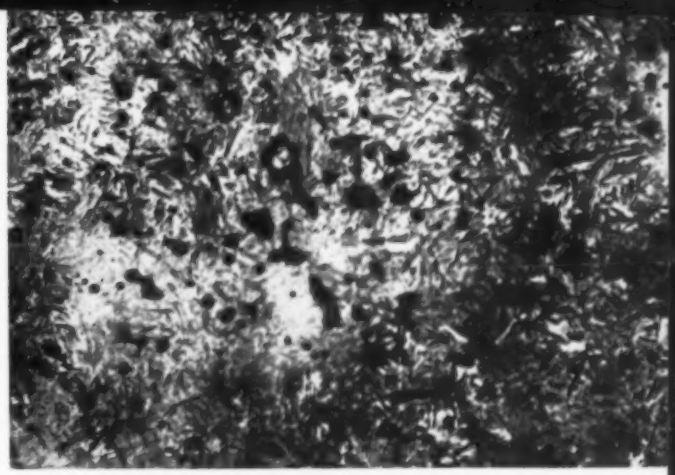


Fig. 4 – Photomicrograph of Low-Alloy Iron Powder Shows That Alloying Is Far From Complete

It is rather surprising that high physical strength is associated with what is apparently poor diffusion and dissemination of the alloy materials, but the fact is indisputable. While proof has not yet been obtained, we feel that the visible alloying is not truly representative of the actual alloying state. The method used to produce the powder has possibly resulted in a degree of alloying which is not resolved by the microscope, but which governs, to a great extent, the final strength of the compacts. Further work is under way to establish reasons for the high strengths of compacts made from alloy powders. In view of superficial alloying, the response to heat treatment is surprisingly good and hardenability is excellent for so porous a material.

Because fabricating experience at Republic is limited, we felt it was desirable to consult representative manufacturers of powdered parts to confirm our findings. The tests were substantiated, and our alloy powder is now being evaluated for use in parts which had previously not been considered for powder metallurgy. It is also being looked at as a substitute for infiltration.

New Horizons

Work is progressing in our laboratories to develop better alloys and to learn more about heat treatment and powder behavior under different conditions. The limitations normally imposed by briquetting pressure still exist, however, and except for rare instances where large pieces can be made, the powder field will generally be restricted to relatively small parts. But a study of the millions of small drive gears, cams, latches, pawls, and other items which are subjected to high loadings should reveal a great number of applications which can profit from the low scrap losses and precise fabrication technique associated with powder metallurgy.

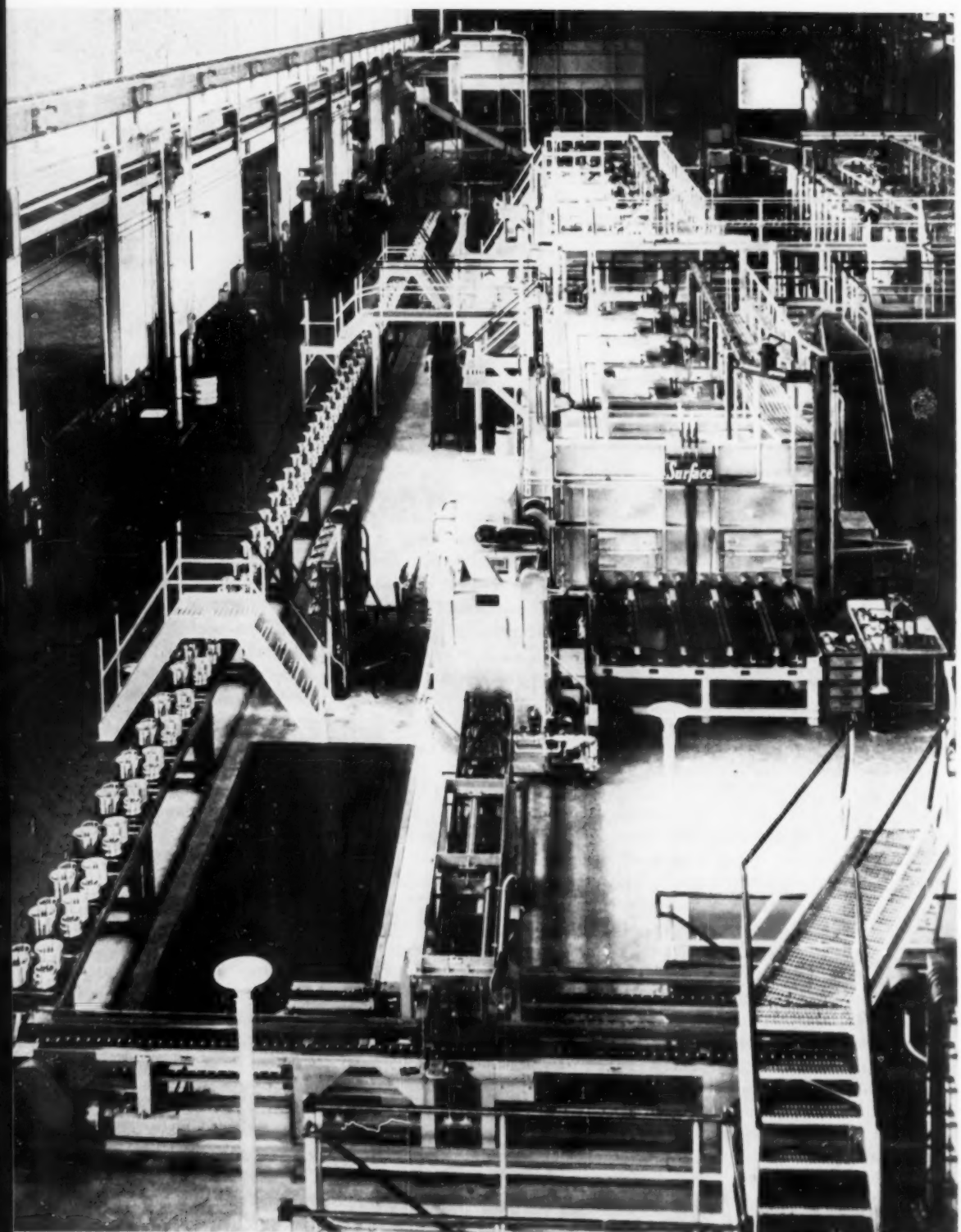


Fig. 1 – Machined Cups and Cones Ready for Carburizing

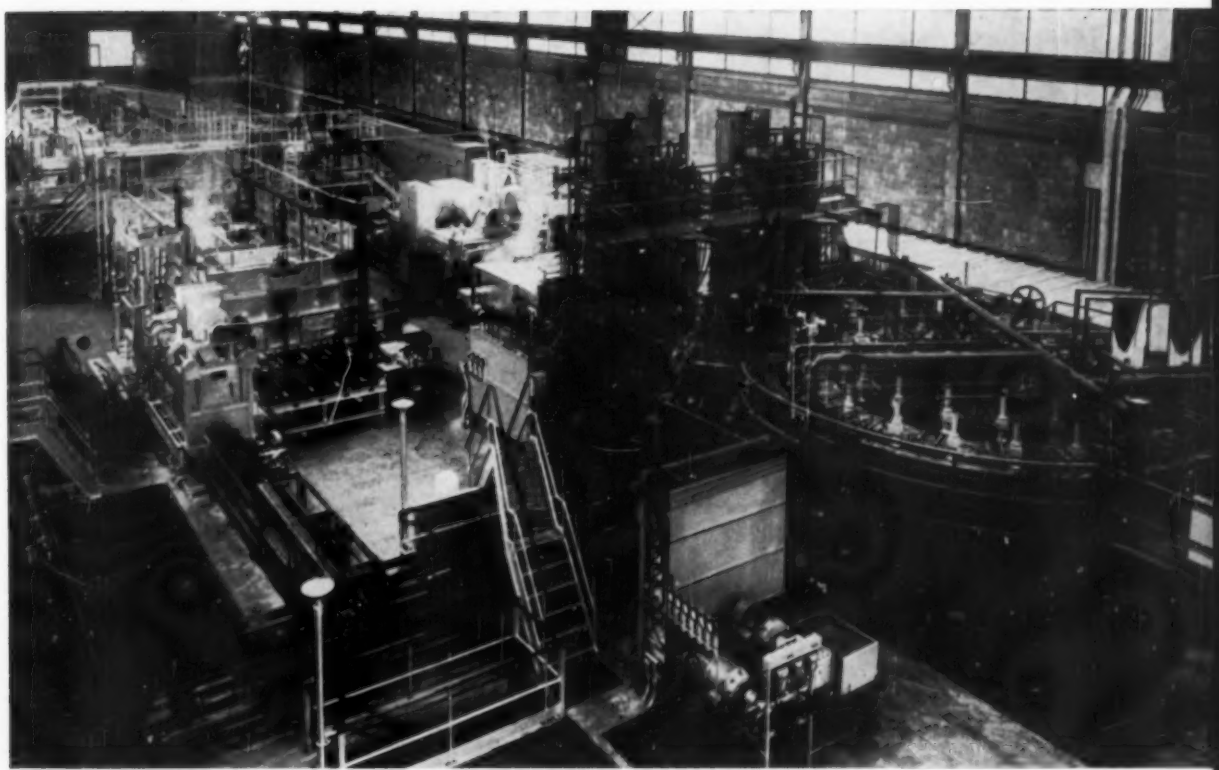


Fig. 2 – Over-all View of Cup and Cone Heat Treating Department. In the foreground are the rotary furnace and the high-temperature tempering furnace. The storage conveyer is at the left

No Waiting in This Heat Treat Line

*By LEO N. EVERITT and CLARKE C. SYKES**

In *Metal Progress* for June 1958, Timken's plant at Bucyrus, Ohio, for automatic production of 27,000,000 roller bearings a year was described. Recently, the company unveiled its Columbus, Ohio, plant for railroad roller bearings. Here, as at Bucyrus, much of the success of automatic production is credited to a completely mechanized operation for carburizing and hardening. (J28g, W27g, 18-74, T7d; ST)

THE HEAT TREATING department at the Columbus, Ohio, plant of the Timken Roller Bearing Co. functions as a single machine to automatically process five standard lines of railroad roller bearings. Cups and cones are carburized, hardened and drawn with manual handling only at the start and finish of the entire heat treating process. Figure 2 shows the setup as it appears in the plant. The equipment includes two gas carburizers, one high-temperature

*Heat Treat Specialist, Timken Roller Bearing Co., Canton, Ohio, and Supervisor of Mechanical Design, Surface Combustion Corp., Toledo, Ohio, respectively.

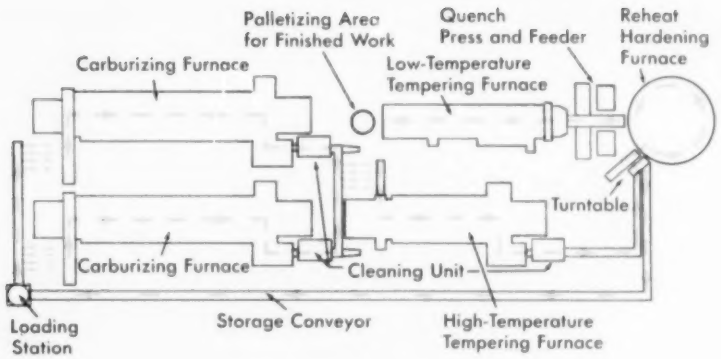


Fig. 3 – Schematic Drawing of Heat Treating Setup. Only four men are needed for operation; they load and unload the pallets, and monitor the recording instruments

tempering furnace, four combination "wash-rinse-dry" machines, one reheating furnace, two quench presses, and one low-temperature tempering furnace. These units are tied together by a handling system which includes several types of conveyers, transfer machines and other automatic devices. The installation is shown schematically in Fig. 3.

Carburizing

In actual operation, cups and cones (machined from A.I.S.I. 3310 steel) arrive on pallets to the return and storage conveyer. One of the four men employed in the heat treating department loads two cups and four cones on each tray. These trays travel along the conveyer (Fig. 1) to the carburizing furnace loading station where they are automatically placed on one of two furnace charge cars; each charge car holds five trays.

The furnace door to the vestibule is actually a plug-type door, integrally mounted on the end of the charge car. Since the end of the charge car serves as the door, the car seals the furnace as it enters on an automatic time cycle. At the end of each purging cycle, an inner door opens and the five trays are individually pushed onto each of the five rows of furnace rails. After the inner door is closed, the charge car backs out of the vestibule for reloading and immediate recharging.

Pusher bars for each row push tray against tray to advance them through the furnace. There must be a full complement of trays for the furnace to function because each time five trays are loaded, five are automatically discharged, one tray at a time. There are 29 trays in each row. When the work is ready to unload, the inner door automatically closes, and stripper rods begin the discharging cycle.

Each stripper has two pull-out bars which enter under the tray to lift it about ¾ in. off the rail. When the stripper withdraws, the tray comes in contact with a bumper which forces it into the path of a push-out arm. The discharge door opens automatically. After the tray is pushed to an elevator located above the hooded oil quench outside the furnace, the discharge door closes. The elevator then lowers the tray into a 3-min. timed quench.

When at the bottom, the tray moves across the quench tank and onto a "discharge elevator." This rises and puts the tray on a drain table. A quench "pull-off" device forces the tray in contact with a limit switch which activates a dog-beam conveyer. The trays are advanced in line through a spray-washer, rinse and dryer. The "dry" tray is automatically placed on a conveyer leading to the high-temperature tempering furnace.

Like the carburizing furnace, this is also a five-row unit. Gas fired by suction-type radiant tubes, it heats 2150 lb. of bearing components to 1100° F. and holds them at this temperature for 4 hr. This furnace is large enough to temper all work processed by the two carburizing furnaces. An inert atmosphere, which is nonexplosive, nonoxidizing and nonsooting, protects the work. The tray loads are quenched, one at a time, to cool the work sufficiently before exposure to outside air. Tempering of the as-quenched cups and cones helps maintain a relatively low austene content in the completed bearing parts.

The tray is pushed from the conveyer to the tempering furnace loader. When five trays are collected, it automatically loads the charge car which carries the parts through the tempering and quenching and cleaning operations.

The trays arrive at the rotary furnace and are channeled to a turntable which orients the trays

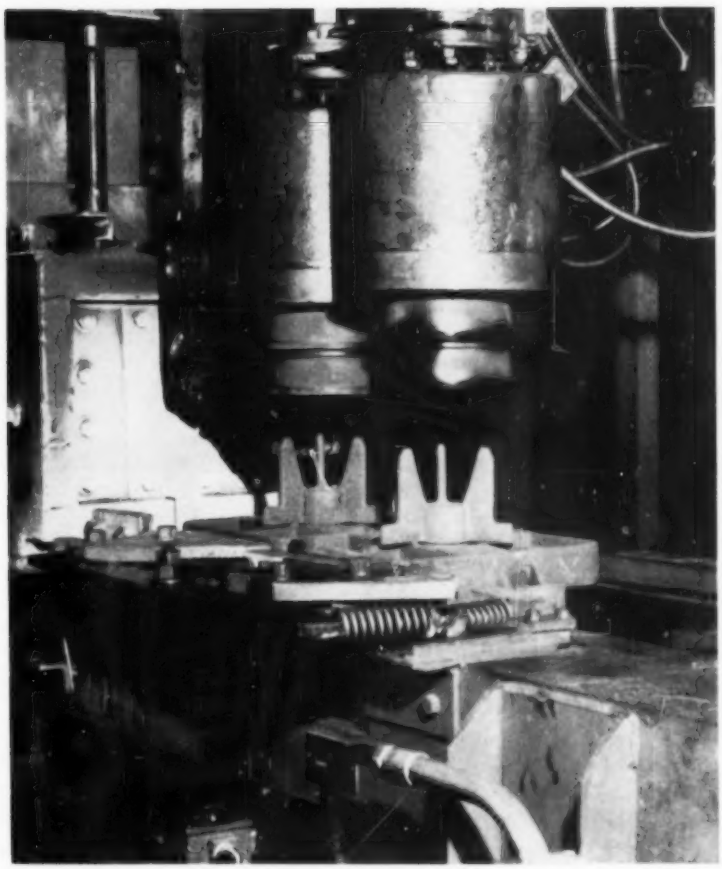


Fig. 4 – Magnetic Loaders in Pickup Position. Shuttle car holds trays ready to load into furnace

to position the parts under a set of electromagnets. A shuttle car, synchronized with the magnet's motion, removes an empty hot tray from the rotary furnace. The magnets transfer two cups from the carburizing tray to the shuttle-car tray (Fig. 4). The shuttle car charges the tray into the furnace and removes the next empty tray from the rotary furnace. The turntable then rotates 90°, orienting four cones under the magnets, and the magnets transfer the cones to the furnace tray which is then charged by the shuttle car. This sequence (alternately loading a tray of two cups, and then a tray of four cones) is continued. Since the cups are always higher on the trays, even though the cones are stacked two high, they are always magnetically loaded and unloaded first. Cups and cones are loaded alternately to insure a continuous and alternate flow of production. From the rotary furnace the parts are fed to two press-quench units, one for cups, the other for cones.

Features of the Rotary Furnace

Leaving the cups and cones at the discharge end for a while, we will discuss the rotary furnace. It is a circular refractory hearth furnace operating on a conventional turntable principle. Fired by vertical W-type suction radiant burners, it reheats 25 complete sets of cold bearings per hr. to 1460° F., with ½ hr. for soaking in a protective atmosphere.

Furnace trays are used to space the work properly for the press quenching operation. The quench press feeders must have cups (or cones) placed on trays large enough to space them to 21-in. centers. If a conventional tray this large were used, the rotary furnace would need twice the floor space it now occupies. Therefore, specially designed trays are used; they collapse before entering the furnace and expand while being removed from the furnace.

Completely loaded, the rotary furnace holds 44 sets of linked trays. Each set holds two cups

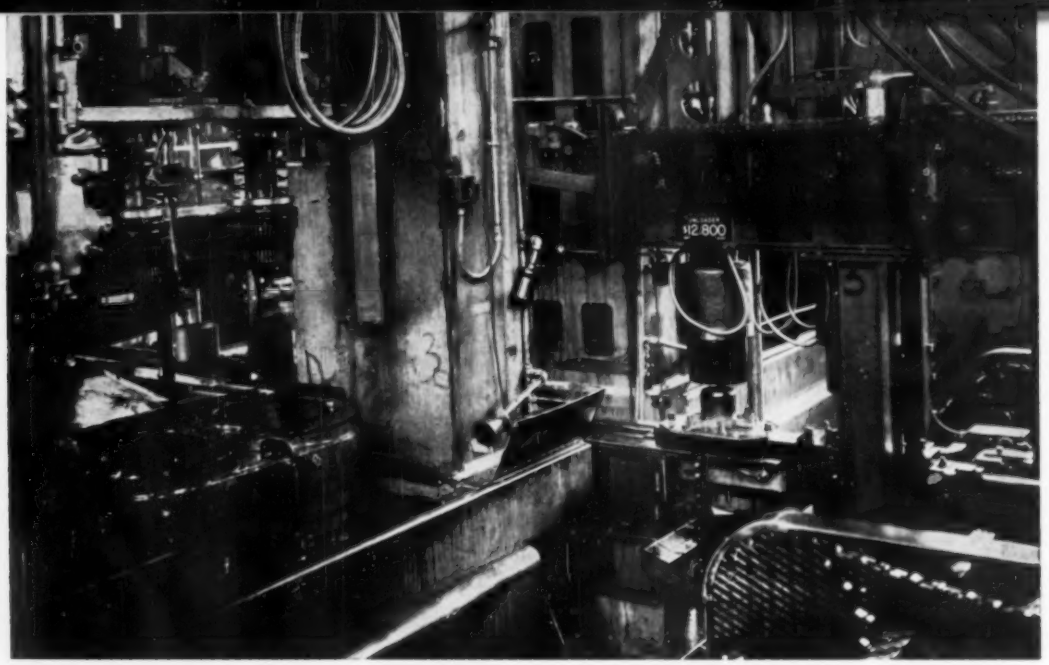


Fig. 5 – Discharge End of Rotary Furnace. Two cups are in the left background ready to be loaded into the press fixtures by the feeder head. Both are in the left foreground. At right, magnetic unloader takes quenched pieces to low-temperature tempering furnace

or four cones. There are normally 40 sets of railroad bearings in the furnace and four empty trays between the discharge and the charge door. This separation of work prevents cooling of parts in the discharge position by the cold parts being charged into the furnace.

If there is a work stoppage at the rotary furnace, or points beyond, work traveling from the tempering furnace automatically bypasses and is channeled directly to the storage conveyer. This permits unimpeded operation of the carburizing and tempering sections, if the reheating process should need adjusting.

Quench Presses

And now, back to the cups and cones. Upon discharging, the shuttle car removes a set of cup-loaded trays from the furnace, the cups to be placed into the quench press. Because the quench rings are spaced on centers much greater (21-in. centers) than the spacing permitted by the furnace hearth (11-in. centers), the trays used in the rotary furnace are linked to form a single tray which can be extended to form a tray with a 21-in. center distance for pickup by the feeder mechanism. There are two separate feeders; one for the cup quench press and one for the cone quench press.

The two arms take the parts from the trays and lower them into the rings. Oil, under pressure, performs the quenching operation. After the parts are quenched, they are drained and placed on the discharge shuttle (Fig. 5). When hot work is pulled from the furnace, quenched work is automatically moved under magnets for transfer to belts.

Low-Temperature Tempering Furnace

After final reheating and quenching, cups and cones are washed and rinsed. The low-temperature furnace tempers 25 complete sets of bearings per hr. at 325° F. with a total cycle of 2½ hr. A fan circulates hot gases through the furnace at a rate of 800 cu.ft. per min. When the cycle is finished, the cups and cones are loaded on pallets to be conveyed to the finishing department. There, they are assembled into complete roller bearings.

The carburizers use gas supplied by three Surface "RX" generators of 3600-cu.ft. per hr. capacity, with natural gas added to provide carbon potential. The high-temperature tempering furnace uses gas from an "NX" unit of 5000-cu.ft. per hr. capacity. The rotary hearth furnace uses a combination of RX and NX generator gases.

Each carburizing furnace has six zones with gases entering the furnaces at several points and being circulated by five fans in the roof of each furnace. Operating temperature is 1700° F.

Parts are conveyed on square, grid-type trays. They are designed to be used on both sides so that when normal distortion develops from continued usage, the trays can be turned over.

Fixtures, trays, rails, hearth plates, heating elements, pushers, and other parts used on the high-temperature furnaces are built of cast alloys, ranging from 9 to 60% nickel, and 21% chromium. Parts and handling mechanisms for the low-temperature tempering furnace are primarily made of cast iron and steel.

Automatic Controls

All automatic functions in this heat treating operation are controlled through a three-section panel connected with an audible alarm system. Lights mounted on one section represent the operating elements and indicate their status of operation. The other two sections display a complete wiring diagram of the system. Indicating lights on these sections of the plastic panel represent every electrical operating device. Recessed terminals in the plastic permit insertion of a probing instrument enabling the operator to locate electronically the source of any disturbance. When the point of malfunction has been determined, the operator relays the information over a public address system or by intercom phone to the attendant.

All mechanical devices on the furnace (such as pushers, quench tank mechanisms, doors, and other operating equipment) can be operated manually when disconnected from automatic operation. This facilitates emptying the furnace for general maintenance. Temperature controls are located on two large panels extending along one side of the heat treating furnaces. These panels contain 21 instruments, including Leeds and Northrup round charts, Speedomax recording controllers and two Leeds and Northrup strip chart recorders for dew point record of RX generator gas and carburizing furnace atmosphere. Also a Bailey combustibles meter monitors and controls the composition of the gas from the NX generator. All motor and other control switches are located on one panel.

Since heat treating involves factors of time, temperature and chemical reaction at the surface of parts being treated, this installation incorporates the latest equipment for automatic precision control. Time cycles are controlled by centrally located timing devices. Temperature is controlled by Leeds and Northrup recording controllers. RX generator gas and furnace atmospheres in the two carburizers are controlled by Surface "Autocarb" dew point signalling controllers, in conjunction with automatic proportioning devices.

The carbon potential is maintained by using proportionate amounts of RX generator gas (at a controlled dew point) and methane (from natural gas). Four "Autocarb" dew point controllers are used with each of the carburizing furnaces. An additional unit is used at each of the RX gas generators.

Carbon potential of 0.95% $\pm$ 0.05% is constantly maintained in the furnaces by maintaining a dew point of 11° F. $\pm$ 1°. The controllers do this by adjusting valves to supply the proper amounts of natural gas. These controls all help to maintain the case depth between 0.048 and 0.062 in., varying with the size of the bearing. Case concentration at the required depth is held at the 0.50% carbon level.

Even with the assurance of automatic control equipment, the company continues constant testing. During the carburizing process, dew point readings are systematically taken, and a complete gas analysis is also made. Tests are conducted to assure that correct case depth and carbon level are maintained.

Emergency Power Source

If the main power source fails, the personnel are alerted by warning lights, horns and other detecting devices. When that happens, an emergency source can be cut into the main power panel. The main switch will activate a time switch, which changes the source of the power in 47 cycles. If primary power is resumed, it reconnects automatically.

There are even provisions if this emergency power source should also fail. Since the heat treating setup would be forced to shut down, some power is needed to empty the furnaces. An auxiliary unit, comprising a motor generator powered by natural gas, can be cut into the system. This unit furnishes sufficient power to operate the door pushers and conveyers needed to shut down the installation in an orderly manner. This threefold power setup prevents damage to the equipment and saves material in process, in the event of total power failure.

Control of the entire process is so completely automatic that bearing quality has practically become an automatic factor. Control keeps variations to absolute minimum, case depths are maintained, and carbon level from surface to required depth is more consistent. The continuous operation and control of the process aids greatly in the production of uniformly high-quality bearings.

Atomic Energy for Space Propulsion*

"Space Hot Rods May Zoom to Other Planets" – that headline in a recent newspaper called attention to the meeting of the International Astronautical Federation held late in August in Amsterdam, Holland. Just as in many such notices of meetings here or abroad for several years, where propulsion systems for missiles, rockets, and space vehicles were discussed, there appeared a reference to "engines using atomic energy . . .".

Projects "Pluto" and "Rover"

It has been no secret that atomic engines have been studied as proper equipment for primary flight propulsion by various governmental and civilian agencies in the United States. These engines could utilize either the fission process or the fusion process. The required research and development have been stimulated by Sputnik and his brothers.

Prior to that time two exclusive studies were under way on two types of atomic propulsion systems. One was named "Project Pluto" (a ramjet system) and the other "Project Rover" (a rocket system). These two projects were carried initially by the U.S. Atomic Energy Commission at the Livermore and Los Alamos Laboratories, respectively, with moderate support from the U.S. Air Forces and certain civilian groups (among them being Atomics International, Martin Co., Wright Aeronautical Corp., Marquardt Aircraft Co., and Thompson Products, Inc.), either with or without signed contracts.

Propulsion Systems

There are two major phases in space propulsion. But first it might be well to define some nonmetallurgical terms. *Propulsion* (either in our own atmosphere or in outer space) is a reaction as a result of waste, or rejection, or expenditure of matter. *Thrust* is the force in pounds acting longitudinally to propel the vehicle forward. Generally it is measured in terms of *specific impulse,* which is the thrust received when propellant is burned at the rate of 1 lb. per sec.

Now to get back to space propulsion. The first phase is a "booster phase" to project the object or vehicle to a certain target on the ground or (alternatively) to place it into an orbit. This takes a very high thrust. The other is the "sustaining phase", necessary once an orbit is attained. Here, low-thrust systems capable of operating for a long time are required. Once an orbit is attained, gravitational forces are balanced by centrifugal forces, and the size of the sustaining phase is only that required to overcome friction or impact of the rarefied atmosphere or meteoric dust. A satellite orbit is a gravity-free system, and a satellite may be accelerated with very little force. For example, the thrust required to get an intercontinental ballistic missile off the ground is 1.4 times its weight. If it were in orbit, the sustaining rate is one ten thousandth as much.

So much for the general idea. What energy source or propellants are available? They may be chemical or nuclear.

Chemical propellants are materials which burn rapidly in oxygen and produce a maximum number of thermal units per unit weight. In a rocket the oxygen is carried in the vehicle; in the ramjet the oxygen is from ingested air. The fuel and the oxygen may be either liquid, gaseous, or in solid compounds. The best combinations mentioned in the published document are fluorine and hydrazine (N_2H_4), which when reacted with oxygen provide specific impulse of 300 to 400 or about 20% more than the best of the other combinations of chemical propellants. Even this does not compare with the controllable specific impulse from nuclear reactors, which is calculated to be two to four times greater – that is, from 1000 to 1200.

Speaking generally, the duration of a flight is limited by the supply of propellant gases, whether heated by chemical reactions or by nuclear fission. Interest in the latter comes from the belief that more net thrust and greater velocity may be obtained because propellant gases of lower molecular weight can be used at higher temperatures.

Furthermore, the nuclear systems will provide desirable thrust for a vastly longer time than any known chemical system. This will avoid second and third stages of thrust to attain desired speed and range. Study suggests also that a nuclear rocket weighs less than a chemical rocket for a given payload.

One calculation finds that a device with a 750-lb. nuclear engine in a 550,000-lb. vehicle

*By Arthur W. F. Green, Technical Consultant, long chief metallurgist of Allison Engine Div. of General Motors Corp. Information from "Hearings Before Joint Committee on Atomic Energy, 85th Congress", Jan. 22 to Feb. 6, 1958.

could place the 100,000-lb. nose cone of an intercontinental ballistic missile on a target 9750 miles from launching. Or the identical vehicle could put a 100,000-lb. satellite into orbit 230 miles above the earth. This would require the propulsion system to run from 5 to 6.5 min. Compare this with the Vanguard vehicle, weighing 21,000 lb., which put a satellite into orbit weighing only 0.1% of its gross weight (about 20 lb.).

Reactor Development

A reactor designated "Kiwi A" for Project Rover rocket system is expected to be operating in late 1958 at a Nevada testing site. This is a high-temperature, gas-cooled device of moderately high power density. Kiwi A is a land-based prototype, not expected to fly, and weighs about 11,000 lb. Initially helium will be the propellant gas, with the probability of using hydrogen later on. Propellant flow is to be controlled for outlet temperatures between 3500 and 5500° F. The time for the nuclear reactor to reach effective temperature for heat transfer to large volumes of gaseous propellant at high flow rates will be measured in seconds, and this suggests the need for a fast-acting control rod system if catastrophy is to be avoided.

Another reactor, "Tory 2", is being prepared for test at the Nevada site for Project Pluto (the ram-jet system). This device is a scale model of one for flight purposes. The difference in temperature of the air from the ram-jet diffuser and the tail cone from the reactor is said to be "just fantastic"!

It is evident that there are major problems to be solved for either the ram-jet or the rocket system. Among them are (*a*) materials for the nuclear reactors, (*b*) ingenious mechanical engineering, and (*c*) nuclear physics, particularly rapid heat development and transfer and the sustaining of such high temperatures.

Other propulsion systems under study which were mentioned in the document under review include pulsed gaseous reactors, nuclear bomb explosions under confinement, and combinations of rods of fissionable material.

Materials for the ram-jet reactor must be oxidation resistant, maintain desirable strength at 5000° F. or more, and be compatible with high radiation intensity. Components of a nuclear system for rocket propulsion need not be oxidation resistant, since most propellants under consideration provide reducing atmospheres.

Carbides of zirconium or tantalum make promising reactor components. Tantalum carbide retains desirable mechanical properties to nearly 7000° F. but it is not oxidation resistant. Tungsten cannot be used in an oxidizing atmosphere. Fuel rods and many structural components will probably use ceramic materials but any such material worthy of consideration must have adequate strength up to at least 5500° F., resist oxidation, be impervious to fission fragments, and withstand thermal cycling.

Secondary power sources will be required for satellite propulsion and for outer space travel. Projects now under way include "Snap" – a nuclear power source to drive electrical equipment for a satellite; "Snap 1" – using radio-isotope cerium-144 or the radioactive metal polonium as heat source; "Snap 2" – a thermal reactor to generate electricity; and "Snap 3" – probably the most exotic of all. It is based on original work by the Russians, who used a large number of thermocouple junctions in series to generate a continuous current. The device described very sketchily in the Congressional document uses "materials of mixed valence oxide" to form a thermopile and preliminary studies show that the efficiency of conversion of heat to electricity is 8%. This system, providing 3 watts of electrical energy for six months, weighs no more than 10 lb., and it is thought that this is the nearest approach to the direct conversion of nuclear to electrical energy yet devised.

Relatively small sources of secondary power are needed to operate recording equipment or send radio or television signals. Likewise a small extra thrust, long continued, would convert a satellite into a space traveller. Many exotic physical devices, including electric currents from photocells, have been suggested for this purpose. Obviously if atomic energy is used for secondary energy, the reactor should be comparatively light – probably less than 10 lb. per kw.

Intensive study has also been given to biological shielding during flight, and the protection of other components of a rocket, missile, or satellite from atomic radiation or cosmic rays. Another intriguing combination is at least one chemical stage for propelling an otherwise nuclear-powered vehicle from the ground into those higher altitudes where the nuclear plant would take over with minimum deleterious effects from gamma and neutron radiation.

A Biographical Appreciation

James Tucker MacKenzie
1891-1958

● As this issue was going to press, we were saddened to learn of Dr. MacKenzie's untimely demise. American metallurgy has lost a great leader and a fine man.

"Mister Cast Iron" is the apt and well-earned sobriquet given to James Tucker MacKenzie by his colleagues in the cast iron field. After nearly half a century devoted to research in this area, it's a title that fits him even more suitably than his recent official one of technical director for the American Cast Iron Pipe Co. of Birmingham, Ala. For his contributions to cast iron metallurgy have been so wide and diversified that, although focusing on centrifugally cast pipe, they have covered the entire cast iron field.

When Dr. MacKenzie retired two years ago, it marked 44 years since he stepped through the American Cast Iron Co. doors and into an analyst job. Fresh from the University of the South with two new degrees – a bachelor's and a master's, his predominant interest in cast iron metallurgy soon became evident and the company realized that their new analyst was no ordinary metallurgist. He had an avid scientific curiosity, intellectual discipline and sound judgment – all indispensable to the researcher – and he was soon assigned full time to research and experimental work. The caliber of this work was recognized in 1947 when he was appointed a director of the company and its technical director.

One of Dr. Mac's invaluable traits – whether conducting a difficult bit of research or playing a bassoon obbligato – is his realistic approach to his problems – a refusal to gloss over the harsh realities of fact for more pleasant fantasies. He calls a spade a spade – or a pipe a pipe. Some years ago when Acipco was bidding on a large pipe job, Dr. Mac accompanied the sales manager on a preliminary survey as the answer-man for any technical questions which might arise. During one of their conferences, the engineer in charge of the job, a know-it-all type upon whose approval the contract rested, made a statement about water pipe with which Dr. Mac disagreed. And he didn't hesitate to say so at some length, while the frantic sales manager, with visions of a big order missed, tried unsuccessfully to change the subject. Dr. Mac made his point – and, happily, Acipco *did* get the contract.

Perhaps most indicative of his unbounding energies and enthusiasm is the long, long list of technical societies which have his name on their rosters. And he is not just a passive member – the outstanding job he has performed on countless committees, as an officer in the upper echelon of technical groups, as lecturer and author would keep many a man too busy to hold down a five-day week job. In the American Society for Metals, he has been a member for some 35 years, served on the ⊕ Handbook Committee and as the first chairman of the Birmingham Chapter; in 1950 he was named to a two-year term as national trustee. Over a long association with the American Society for Testing Materials, he has served on the Board of Directors of that group and for some years acted as chairman of its Committee A-3; he received an Award of Merit for outstanding service to the Society in 1953. One of the first to recognize the necessity for the statistical approach to the presentation of technical data, he served for seven years on the A.S.T.M. committee which produced the A.S.T.M. Manual on Presentation of Data. (This interest in statistics carries over into his daily life. He is one of the few people who – if asked – can rattle off the mean number of segments in their breakfast grapefruit.)

As with most of his other society memberships, he is a long-term (and honored) member of the American Institute of Mining, Metallurgical, and Petroleum Engineers and served as chairman of its Iron and Steel Div., a director of the Society and in 1944 was the Howe Memorial Lecturer. The American Chemical Society has recognized his service by the Herty Medal of the Georgia Section and the Southern Chemist Award of the Memphis Section.

The Society claiming his most intense interest is the American Foundrymen's Society which awarded him honorary life membership in 1938. Past chairman of the Gray Iron Div. and the Birmingham Chapter, he was elected a director of the Society in 1951. He has been honored by the John H. Whiting Gold Medal and was the first Hoyt Lecturer in 1947. The Institute of British Foundrymen elected him an honorary life member in 1951.

Dr. MacKenzie's work in cast iron metallurgy has resulted in two honorary doctor of science degrees, one from his alma mater, the University of the South, and another from the University of Alabama. In 1951 he was recognized by the U.S. Government for a study made on German centrifugal casting methods as a member of a mission for the Federal Foreign Economic Administration.

Born in Florida and raised in the South, Dr. Mac married a Southern girl, Catherine M. Sharpe, in 1915, and has two children, James Tucker, Jr., and Catherine. Tucker, an active ⊕ member like his father, works with U. S. Steel Export Co. in New York.

When his mind is not on metallurgy, it will often be on music. He is an accomplished organist and a member of the American Guild of Organists. Several years ago, when the Birming-

ham Symphony Orchestra found itself without a bassoonist, Dr. MacKenzie obligingly mastered this instrument. His musical career has not been limited to classical works alone; as a young man he played a hot trumpet in a jazz band.

Aside from music and metallurgy, Dr. Mac's interests are bridge and, as with all scientists, science itself. His scientific interests extend far beyond the reaches of his chosen field.

His current hobby is collecting particularly choice examples of redundant phraseology – a singularly satisfying hobby for anyone who attends as many meetings and listens to as many lectures as he does. His prize is the quote from the chairman who announced firmly, "From now on we're going to have an annual meeting – every damn year!"

"Retirement" is hardly the appropriate word to be applied to James Tucker MacKenzie's present status. Already he is busily engaged in an active consultant business and is a consultant with the Southern Research Institute – a fine start to what promises to be the least retiring "retirement" on record.

Ultra-Pure Metals Produced in Electron Beam Furnace

*By T. C. DuMOND**

Electron melting method, combined with efficient vacuum system and cold crucible casting, reduces impurities in refractory metals to extremely low levels. (D5k, 1-52, 1-73)

PURIFICATION to a degree not previously attainable in melting the refractory metals is possible by a new melting process developed by Temescal Metallurgical Corp., Richmond, Calif. The process, known as electron beam melting, is carried on in a high vacuum. It reduces undesirable impurities to lower levels than are possible by vacuum sintering or arc melting. The result is a pure metal with properties superior to those attained by other methods. The features of the process which make it so efficient in removing impurities prevent its use in melting alloys of the refractory metals for casting.

The desirability of electron beam melting in a vacuum has been recognized for many years, but two obstacles had to be cleared. One problem was to develop a stable electron beam system capable of reducing commercial quantities of metals. The second hurdle was to obtain and maintain a high vacuum in the furnace. Satisfactory solutions to these problems were found and combined with cold crucible casting to arrive at the process now being used. The use of a water cooled copper crucible prevents recontamination of the metal after melting.

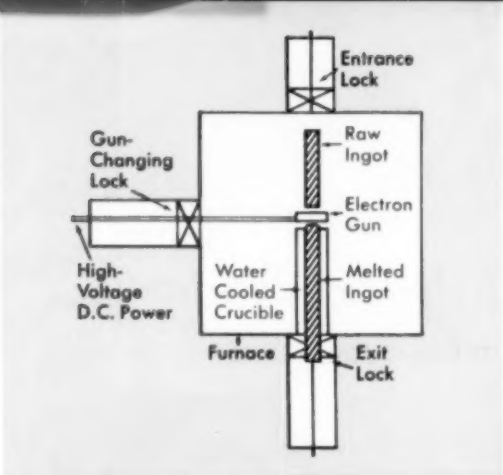
One of the achievements of the new process is to make available commercial quantities of ductile columbium. An example of the possibilities in this area is cold rolling of ½-mil columbium foil from a 3-in. ingot without annealing. Comparable progress is anticipated with tantalum, molybdenum, beryllium, and special steels and stainless alloys. It is also expected that the method can be used to recycle the scrap of many of these metals.

The furnace in which electron beam melting is done is operated under a vacuum of 10^{-7} atmospheres. Heat for melting is provided by an electron gun which serves as the cathode and bombards the melt stock – the anode – with electrons until the melting range is reached. Melting stock can be in the form of ingot, pellet, powder, flake or sponge.

Metal melted by the electron beam drops into a water cooled copper crucible where a molten pool is maintained by electron bombardment from another gun. The surface of the molten pool is kept at a constant level as the solidified ingot is withdrawn downward.

The vacuum required for the process is provided by a system using three types of pumps – oil diffusion, oil jet and mechanical. The system maintains a vacuum of less than 0.1 micron of mercury even at high melting rates.

*Secretary of the Metals Engineering Program Committee.



Electron Beam Melting Furnace

The process results in the volatilization and removal of certain critical impurities. Those forming compounds having vapor pressures of at least 10^{-5} atmospheres at surface of the melt can be removed easily. However, if the vapor pressure of the oxide is lower than that of the metal, compounds will remain while the metal volatilizes. In many instances, carbon, hydrogen and oxygen are removed almost as rapidly as carbon monoxide, metal monoxides and similar compounds.

Two melts are required with most metals. In the sizes of furnaces now used, 10 to 15 lb. of columbium is melted per hour during the first melt. The rate is stepped up to 80 lb. per hr., in the form of 4 ft. of 3-in. diameter ingot, during the remelt operation.

There does not appear to be a limit on the diameter of bar or ingot which can be melted and purified in an electron beam furnace. Equipment of this type is believed capable of producing ingots up to 20 in. diameter, weighing about three tons. As ingot sizes increase, costs are expected to decrease because of the higher output rates.

Electron beam vacuum furnace systems are so designed that cathodes can be replaced, melt stock fed into the furnace and ingots removed without affecting the vacuum except in a localized area which can be returned rapidly to the proper vacuum.

Operating economics of electron beam melting are favorable and will undoubtedly make the process competitive with consumable arc melting and other methods. The process uses high-voltage direct-current electrons which are relatively inexpensive and with which power efficiencies are high. Double melting of columbium requires 5 to 10 kw-hr. per lb. Double melting of tantalum requires 8 to 12 kw-hr. per lb. These figures compare with about 500 kw-hr. per lb. for the solid-state sintering of tantalum.

Because the melting of columbium by the electron beam technique has reached a semi-commercial scale, it can be used as an example of how the method works. The melting of columbium involves the removal of contaminants, such as oxygen, nitrogen and carbon, as well as the vaporization of many potentially desirable alloying elements.

Results obtained thus far show that vanadium and all other metals of greater volatility than vanadium, such as iron, aluminum, nickel and chromium, evaporate rapidly from columbium to extremely small concentrations. For this reason, electron beam melting is not expected to find use in melting oxidation resistant alloys of columbium. Metals such as zirconium, molybdenum and tantalum do not evaporate from columbium at appreciable rates, however. The change in composition of alloys can be estimated quite accurately, using metal vapor pressure data. Each alloy must be looked at separately.

Electron beam melting and casting of columbium at a rate of about 10 in. of ingot per hr. reduces impurities from 2500 ppm. to about 500. Remelting at the same rate lowers the oxygen content to about 100 ppm. Removal of nitrogen to desirable levels requires a somewhat lower melting rate than for oxygen removal. To meet specifications in melting columbium, it is necessary to provide close control over melting rates and to use a melt stock of known quality.

Some points of superiority of the electron beam process over vacuum arc melting and zone melting are:

Raw material can be handled in virtually any form.

For zone refining, the electron beam method can handle larger diameter bars or ingots than conventional zone melting of highly reactive metals.

Vacuums in which electron beam melting is done range from 0.01 to 0.10 micron as compared to a range of 10 to 100 microns in vacuum arc melting.

Arc melting depends upon a low-voltage high-current arc; the new method utilizes high-voltage low-current electron bombardment.

The electron beam process can be started and stopped at any time without loss of material. Should the furnace lose its vacuum, a maximum vacuum can be pulled in about 15 min.

Purification of metal is higher in electron beam melting than in vacuum arc or conventional vacuum induction melting.

High-Temperature Metallurgy Today

*By L. P. JAHNKE and R. G. FRANK**

In an article in *Metal Progress* last month the authors discussed the mechanisms for strengthening alloys which have resulted in improved elevated-temperature materials. This installment carries these considerations into work on developing improved superalloys and refractory metal compositions. The authors also give properties of some of our best superalloys and predict future performance which can be expected from refractory metal alloys. (Q-general, 2-62; SGA-h)

THE CLASS of alloys called superalloys is broad, and includes iron-nickel, nickel and cobalt-base alloys. Addition of nickel to iron alloys allowed the development of a series of austenitic precipitation hardened alloys ranging from A-286, which contains about 25% Ni, to alloys such as René 41, which contains some 55% Ni.

The iron-nickel alloys become progressively superior to the martensitic class of alloys above 1000° F. A-286 alloy is a derivative of the austenitic stainless steels (such as A.I.S.I. Type 330) which is strengthened somewhat by addition of molybdenum, but primarily by the precipitation of Ni_3Ti, a hard intermetallic compound with excellent coherency in this matrix. The alloy is easily formed in the solution treated condition (1800° F., followed by fast cool) and generally is machined after precipitation hardening (1300° F. for several hours). Segregation in large ingots caused some trouble early in its use, but consumable-electrode melting in vacuum solved this problem for ingots up to 20 in. in diameter.

The only serious difficulty with A-286 which has not been adequately solved is its poor weldability. A hot shortness exists, which causes weld zone cracking when residual stresses are even moderately high. Better weld joint fit-ups and careful welding techniques have allowed this deficiency to be tolerated. A-286 will continue to be widely used for sheet metal applications and for forgings (where welding is not required) in the service range of 1000 to 1300° F. More recent alloys in the iron-nickel base field are M-308, D-979 and Unitemp 212. These extend the service range of A-286 some 100° F.

Design curves for the iron-nickel, nickel and cobalt-base alloys are shown in Fig. 1. The nickel alloys, although more difficult to melt, forge and machine, are so outstanding in strength that they virtually have a monopoly on all the new applications above 1000° F. René 41 high-temperature alloy (trade-marked by General Electric Co.) is the best of the commercially available alloys. Other alloys in the group are M-252, Udimet 500 and R-235. Several nickel-base development alloys have outstanding 100-hr. stress-rupture strengths (1800° F., 15,000 psi.; 1600° F., 40,000 psi.; 1200° F., 130,000 psi.). It is evident, especially at the lower temperature, that further strength improvements are possible.

The nickel alloys, typical of René 41, are primarily strengthened by a dispersed second phase, consisting of a solid solution of Ni_3Al and Ni_3Ti, designated as gamma prime phase, [Ni_3 (Al, Ti)]. In addition, they all contain a solid-solution strengthener with a low diffusion rate, such as molybdenum and tungsten. Gamma prime is stable at higher temperatures than either the Ni_3Al or Ni_3Ti phases. This accounts for the

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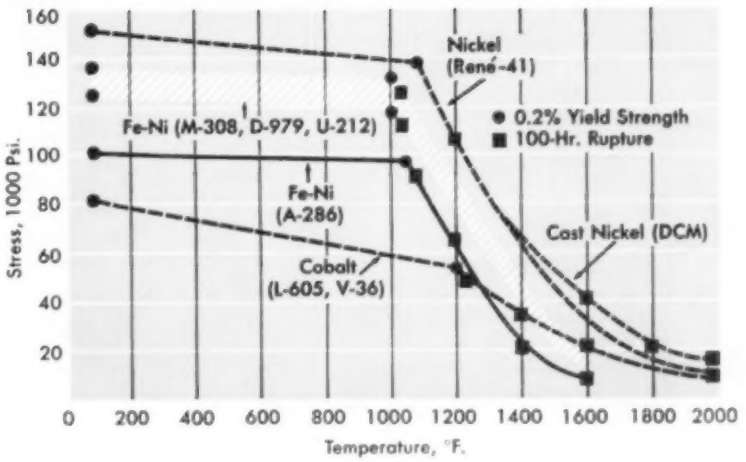


Fig. 1 – Design Curves for Superalloys Comparing Performance Levels of Nickel, Iron-Nickel and Cobalt-Base Alloys

significantly higher strength of these alloys over the titanium-bearing iron-nickel alloys in the range of 1500 to 1800° F.

L-605 and V-36 are the outstanding wrought cobalt-base alloys, even though they were developed many years ago. They are relatively inexpensive and can be readily fabricated. No effective precipitation hardening systems have been found for the cobalt-base alloys; as a result, they have fallen behind nickel alloy development in the past five years.

Cobalt alloys are strengthened primarily by the solid-solution mechanism with large additions of tungsten and molybdenum, and to a lesser degree by a dispersion of stable carbides. Cobalt alloys can compete in strength with those of nickel only in the temperature region where the age hardening phase in the nickel alloys becomes unstable – generally above 1800° F.

Mechanism of Strengthening

The physical metallurgy of the nickel family of alloys is receiving considerable attention. René 41 is strengthened by putting its titanium and aluminum in solution at about 2000° F., rapidly cooling, and allowing the precipitation of gamma prime at some lower temperature where the size and dispersion of the particles are at an optimum value.

Figure 2 shows the range of strengths obtainable by varying the solution treating and the age hardening temperatures. For maximum strength above 1200° F., treatment A (high solution and aging temperatures) would be used. For maximum strength at low temperature, treatment B (lower solution and aging temperatures) would be preferred.

The surface-to-volume ratio of a component operating at high temperature is critical because of oxidation. Titanium and aluminum will be preferentially oxidized at the surface resulting in localized depletion of the gamma prime phase and loss of strength. The higher the temperature, or the thinner the sheet, the lower the overall rupture strength. René 41 loses 80% of its rupture life at 1800° F. under a stress of 10,000 psi. as sheet thickness is decreased from 0.070 to 0.040 in. Designers of minimum-weight aircraft must be aware of changes of this magnitude. Design curves must be obtained with material of the same thickness to be used in forming actual components.

Vacuum melting has beneficial effects on nickel alloys since the titanium and aluminum are kept present as gamma prime particles and not in ineffective or detrimental oxides or nitrides. Data on some 40 to 50 heats of air-melted and vacuum-melted M-252 alloy show that stress-rupture and fatigue strength, ductility, and mill yield are all significantly improved by vacuum melting. Stress-rupture strength is increased simply by the fact that the full effectiveness of the titanium and aluminum is not reduced by the reaction of these elements with atmospheric gases. Improved cleanliness and elimination of stringers of Ti (C, N) are responsible for better fatigue strength, ductility and mill yield.

Brazing Versus Welding

High-temperature brazing is being widely used instead of welding because it causes less distortion of the part and is better adapted to joining very thin sheet. The high titanium and aluminum contents of nickel alloys cause the formation

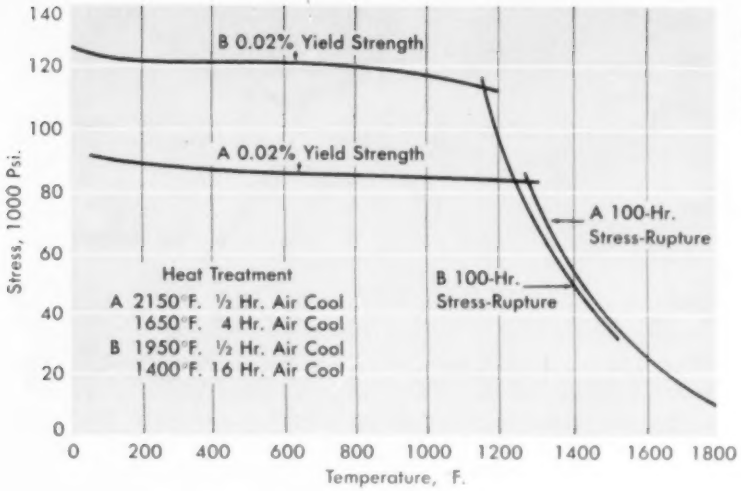


Fig. 2 – Influence of Heat Treatment on 0.02% Yield Strength and 100-Hr. Stress-Rupture Life of René 41 Sheet Alloy

of tenacious TiO_2 and Al_2O_3 surface films which cannot be reduced by the purest hydrogen. These films cause poor wetting by the brazing alloy, giving brazed joints with low shear strength. Vacuum brazing gives much improved shear strength since the oxide films don't form. If an alloy such as L-605, which contains no titanium or aluminum, is similarly compared, no difference in shear strength is found between vacuum and hydrogen brazing.

Castings Are Gaining Preference

Cast nickel-base alloys have been avoided in the past by some aircraft engine producers because of nonreproducible properties and somewhat lower fatigue strength. There are two reasons why castings produced in vacuum are now being considered for applications where maximum high-temperature strength is needed. First, a cast alloy has the same strength at some 50° F. higher than the forged alloy of the same composition. The second reason (and more significant) is that the possible forging temperature range of the more recent alloys is so narrow that it is practically impossible to form them into intricate shapes. Raising the forging temperatures would result in incipient melting of the low-melting phases at the grain boundaries. At lower temperatures, the alloys are too strong and have too little ductility. General Electric's DCM is such an alloy and is one of the strongest oxidation resistant alloys in existence. DCM is probably close to the end of possible advances in the nickel system. However, for lower temperature service, forgings are invariably stronger than cast forms.

The effect of grain size on the strength of cast alloys has at times been a controversial subject. Data on DCM alloy show over a fivefold increase in rupture life at 1800° F. as the grain size is increased from 0.005 to 0.20 in. (Tests were made at 1800° F., 15,000 psi. for about 100 to 500 hr.). The reasons for this increase will be postulated later.

The effect of grain size on fatigue strength of a cast cobalt-base alloy, X-40, is the opposite at lower temperatures. Data show that at 1200° F. small grains result in higher fatigue strength, but the effect of grain size rapidly decreases as the temperature increases to 1600° F.

Some interesting observations have been made on the microstructure of a high-strength, cast nickel-base alloy to help explain the effects of grain size on rupture strength. A profuse amount of fine well-dispersed gamma prime precipitate is found within the cast grains and grain boundaries. Concentration of aluminum near the grain boundaries is evidenced by the greater amount of gamma prime present in this area.

A boride and a carbide phase are also present in the grain boundaries and help prevent coalescence of the gamma prime. It is postulated that with a given boron content the larger grains (having less grain boundary area per volume) therefore have a greater concentration of borides in the grain boundary which prevent the gamma prime from coalescing. However, continued exposure at a high aging temperature (1950 to 2000° F.), but below the solution temperature of gamma prime (about 2100° F.), results in coalescence and growth of the gamma prime particles accompanied by a loss in stress-rupture life.

Comparison of the Refractory Metals

Element	Advantages	Disadvantages
Tungsten	Highest melting point; nonvolatile oxide to at least 2500° F.	Highest density; oxidizes rapidly; brittle at low temperatures.
Tantalum	Very high melting point; nonvolatile oxide; ductile.	High density; oxidizes rapidly; least abundant.
Molybdenum	High melting point; less dense than tungsten or tantalum; moderately ductile at room temperature.	Extremely high oxidation rate (volatile oxide).
Columbium	High melting point; nonvolatile oxide; ductile; moderate density.	Oxidizes rapidly.
Chromium	Extremely oxidation resistant; lightest of refractory metals.	Lowest melting point of refractory metals; brittle at low temperatures.

The high melting point of refractory metals – tungsten, tantalum, molybdenum, columbium and chromium – must be developed to achieve high strength above 2000° F. Generalizations, which can be used in comparison of these metal systems, are given in the table. It's quite probable that the higher oxidation resistance and lower density of columbium will make it the most attractive of these metals up to 2500° F. Up to 3500° F., molybdenum will take over and, above this, it will be tungsten-base alloys. Obviously, tungsten is our only hope, with our present understanding of science, of using metals at temperatures up to 5000° F. – 80% of the melting point of tungsten.

Molybdenum, because of its availability, cost and density, has received the most attention of the refractory alloys and is the most advanced. Recently other refractory metals have been receiving more attention because of (*a*) greater strength potential above 3000° F. (tungsten) or (*b*) superior oxidation resistance (columbium especially). These alloy systems are compared in Fig. 3 with the best cast nickel-base alloys (DCM) and with the advances being made in the molybdenum system. These conclusions can be drawn:

- All the refractory metals are stronger than the best nickel alloys above 1600° F.
- Slight alloy additions to molybdenum have a great strengthening effect.
- Some progress has been made in the columbium system but small alloy additions are not as effective as in the molybdenum system.
- The strength of unalloyed tungsten is good at 2200° F. (Recent reports show that a tungsten-rhenium alloy, in the early stages of development, possesses remarkable strength at 3000° F.).

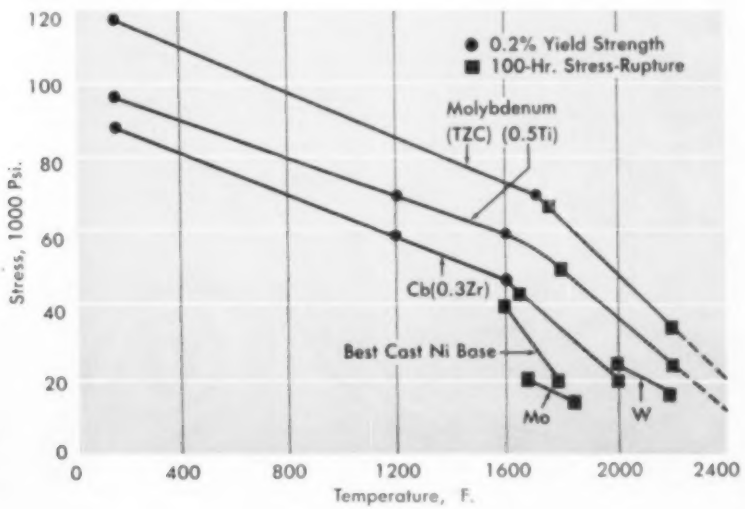


Fig. 3 – Today's Best Refractory Alloys Compared With the Best Cast Nickel-Base Alloys

The real impetus on molybdenum came after the introduction (by Climax Molybdenum Co.) of the alloy containing 0.5% Ti. It was the first commercial composition with a high recrystallization temperature (2450° F. – 1 hr.). The primary strengthening mechanism for molybdenum is work hardening (pinning of dislocations by other dislocations), and the degree of work hardening is critical. As the amount of cold work is increased, the low-temperature strength (to 1600° F.) is increased. However, severely worked material (over 90%) will recover at a much lower temperature than metal worked an optimum amount (60 to 75%) and, thus, will lose much of its strength at the higher temperature (that is, above 2000° F.).

The maximum strengthening effect in molybdenum-titanium alloys containing up to 5% Ti occurs at ½% Ti and is due to dispersed second phases tentatively identified by W. Chang* as TiC and Mo_2C. Additional strengthening at higher temperature is due to the increase in recrystallization temperature and, thus, a delay in the recovery process.

A need is developing for alloys with an even higher recrystallization temperature than molybdenum containing ½% Ti. This comes from the high temperatures required for the application of new protective coatings and more advanced propulsion systems. Although increased titanium is beneficial from this standpoint, carbon is even more effective. A cold worked 5% Ti, 0.25% C alloy did not recrystallize even after 1 hr. at 3000° F. Increased carbon in these alloys, however, did nothing to improve the strength outside of delaying recovery.

A high-strength molybdenum alloy (in fact, probably one of the strongest alloys known for use above 2000° F.) is a composition developed by G.E. containing 1.25% Ti plus 0.15% Zr and 0.15% C (TZC alloy in Fig. 3). The 100-hr. stress-rupture strength of this alloy at 2200° F. is 34,000 psi. (200° F. better than molybdenum with ½% Ti). The recrystallization temperature in 1 hr. is 2900 to 3000° F. Because of its resistance to softening, it takes much higher temperatures to process – a big problem with today's processing equipment. This development alloy is receiving serious attention and many 100 to 200-lb. ingots have been successfully processed into sheet and bar.

*General Electric Co. Aircraft Gas Turbine Div. Report DM 58210.

Oxidation Problem Is Major One

One property which has prevented universal use of the refractory alloys has been their poor oxidation resistance. Comparison of the oxidation resistance of several refractory metals in Fig. 4 shows the rapid increase in rate as the temperature is increased above 800° F. Molybdenum and rhenium, because of the extremely high vapor pressure of their oxides, go off scale quickly and are shown in the upper portion of the diagram. Most research groups have given up on developing an oxidation resistant molybdenum alloy and are concentrating on external protective coatings. On the other hand, great strides are being made with columbium in developing alloys with adherent protective oxide

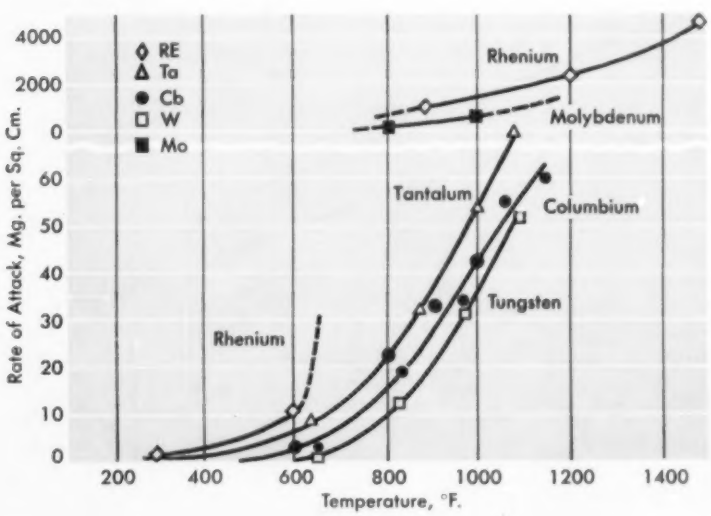


Fig. 4 – Oxidation Rate of Refractory Metals. There is a rapid increase when temperature goes above 800° F. Molybdenum and rhenium, because of the extremely high vapor pressures of their oxides, go off scale quickly and are shown in the upper portion of the diagram

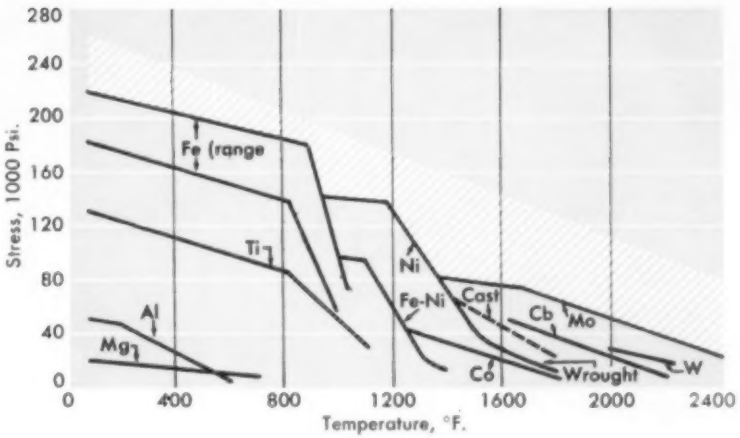


Fig. 5 – Strengths of Various Alloy Systems for Elevated-Temperature Service. Shaded areas will be filled by new alloys as high-temperature metallurgy moves ahead

scales though nothing is yet known about their strength. A characteristic peculiar to columbium and tantalum is their ability to dissolve large quantities of gases (O_2, N_2, H_2) which, if not controlled, results in complete loss of ductility even at 2000° F. Alloying can also minimize this tendency.

Because of the oxidation problem, serious consideration is being given to aircraft and space propulsion devices designed to use refractory metals in an inert atmosphere. This should be a happy note for all high-temperature metallurgists. However, until then protective coatings are necessary. Otherwise, life expectancy of the desirable application must be short (as in missiles) so that rapid oxidation can be tolerated.

As a summary for the refractory metals, let us say that we have come far in understanding the many difficult problems associated in their use, such as melting, conversion, fabrication of components and also the problems of actual operation of parts at high temperatures. That some success is being achieved in the application of refractory metals is indicated by the photograph of a General Electric jet engine operating with turbine temperatures in excess of 2000° F., using coated molybdenum buckets, shown on the cover of *Metal Progress* last month in conjunction with Part I of this article.

Today's Picture in Brief

The best alloys of each type are presented in Fig. 5 on an expanded scale. If one were to select only the strongest alloys, choices would be confined to toolsteels, nickel-base and molybdenum-base alloys over the temperature range from 0 to 2400° F. But for reasons of fabrication, cost or oxidation, all of these classes have their own gamut of applicability. Until the oxidation problem is solved or bypassed, nickel alloys will dominate applications in the 1000 to 2000° F. range.

Designers of aircraft and aircraft components are interested in the strength-to-weight ratio. By dividing the strengths of the alloys by their densities, it is found that:

- Aluminum becomes slightly more attractive up to 500° F.
- More significant, titanium is generally competitive at low temperatures, if not with toolsteels, at least with the semi-austenitic stainless steels.
- Nickel-base alloys are still best above 1000° F. and molybdenum dominates applications above 1600° F. despite its higher density.
- Columbium has crept up on molybdenum and unalloyed tungsten has fallen below columbium.

It is wise to remember that designers must also consider stiffness in their calculations and often cannot make parts as thin as the strengths allow because of machining or fabrication difficulties. In these instances, some of the lighter alloys are used to advantage. Also, cost influences choices of materials. For example, if A-286 is satisfactory for an application, René 41 will be ignored; or if alloy steels such as 4340 are suitable, Vascojet 1000 will not be used.

The advances that have been made in high-temperature metallurgy over the past two decades of concentrated effort are just short of phenomenal. But to maintain the pace that is required and expected by other fields of engineering, aggressive creativeness and daring efforts must become commonplace. A mere extrapolation of progress since 1940 will soon fill the shaded area of Fig. 5 with new alloys, but will never fill the insatiable appetite for progress of the air and space craft industry.

A New Direct Reduction Method

By M. J. UDY and M. C. UDY*

Partial reduction of ore by soft coal in a rotating kiln, followed by smelting in an electric furnace, produces iron for further refining. Carbon can be controlled in a 0.2 to 3.5% range, and no special ore preparation is needed. (D8j)

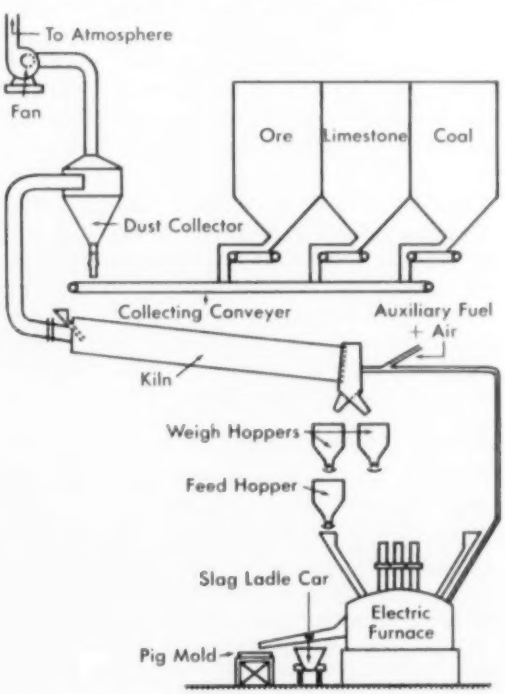
STEEL MEN foresee the day when a complete vest-pocket steel mill can be dropped in the middle of a desert. Such a plant would include an electrical power source, a small ore reduction process, and an electric steelmaking furnace. The latter has been an accomplished fact for years, and self-contained power plants using nuclear energy have also been constructed. All that remains is a practical and economical method for ore reduction. This need, we feel, is answered by the Strategic-Udy process.

How It Works

One advantage is that no special ore preparation is required. Fines and flue dust work just as well as sized iron ore. The process is a smelting technique using a direct-fired rotary kiln that partially reduces the ore before it is charged into an electric arc smelting furnace. All of the heat needed to reduce and heat the charge in the kiln is supplied by burning, in the kiln, volatile matter from coal and carbon monoxide gas. Since these are produced during reduction in the kiln, and subsequent reduction in the electric smelting furnace, the process is self-continuing. Figure 1 illustrates the essential equipment for the process.

A mixture of iron ore, flux and carbonaceous reductant is continuously fed to the rotary kiln. During the operation, the iron ore is heated, calcined and reduced, and the flux (lime, quartz, or other) is calcined and combined chemically with the ore. The free-flowing kiln discharge is controlled between 1800 and 2300° F. This tem-

Fig. 1 – Flow Diagram of Strategic-Udy Process. Carbon monoxide produced in the electric furnace is recycled to the kiln where it aids in heating of the ore charge



*Vice-President and Director of Research, respectively, Strategic-Udy Processes, Inc., Niagara Falls, N.Y., a subsidiary of Strategic Materials Corp., Buffalo, N.Y.

Fig. 2 – Feeding Kiln Product to Electric Furnace. The hot, partially reduced ore slides down the furnace sides directly into the reaction zone

perature varies with nature of the ore. Above this temperature, the hot charge material starts to cake and adhere to the kiln walls. Sufficient coal is added to accomplish the required two-step reduction. The coal not used for prereduction (or burnt in the kiln) is "coked" and passes out with the prereduced material. It acts as a preheated reductant in the electric smelting step.

To save thermal and electrical energy, the hot prereduced ore is charged from the kiln directly to the smelting zone of the electric smelting furnace through insulated feed control bins and controlled feeders. The process employs an open bath technique around the electrodes with the electrodes from ½ in. above the molten slag to 3 in. submerged in the slag, depending upon the particular operation. As charge material enters the furnace, it forms its own angle of repose. Thus the space above the electrodes is open and offers no restriction to the flow of carbon monoxide gas produced during reduction, and the molten bath furnishes electrical resistance permitting high and uniform power inputs. Fines work perfectly in the operation and may be used exclusively if the situation warrants. Carbon monoxide formed during reduction is collected and burnt in the kiln.

The carbon content can be varied from 3.5% (pig iron) to 0.2% (steel) with comparative ease by accurate control of slag composition and amount of reductant. Contaminating elements such as titanium, manganese, phosphorus, chromium and nickel can be removed. They can also be recovered if present in sufficient concentration. Where exact carbon control is required, finishing additions of reductant can be introduced in the smelting furnace or carbon adjustments made by addition of iron ore. Iron and slag are tapped intermittently and handled in the conventional manner.

Economics of the Process

The process has been evaluated at the Niagara Falls prototype plant. This plant includes three electric smelting furnaces, an 80-ft. kiln and all necessary auxiliary equipment, including a laboratory for quality control and chemical analyses. A number of runs using various ores and carbonaceous materials were made to determine comparative costs.

In a recent demonstration run in this plant, more than 260 tons of metal was produced, having a weighted average of 1.74 C, 0.15 Si, 0.117 S, 0.06 P, 0.11 Mn and 0.04 Ti. Three series of tests were made, each at a different carbon level in the metal. In the first series, carbon varied from 2.00 to 2.75; in the second series, it varied from 1.02 to 1.92, and in the third series, the carbon varied from 0.17 to 0.92%.

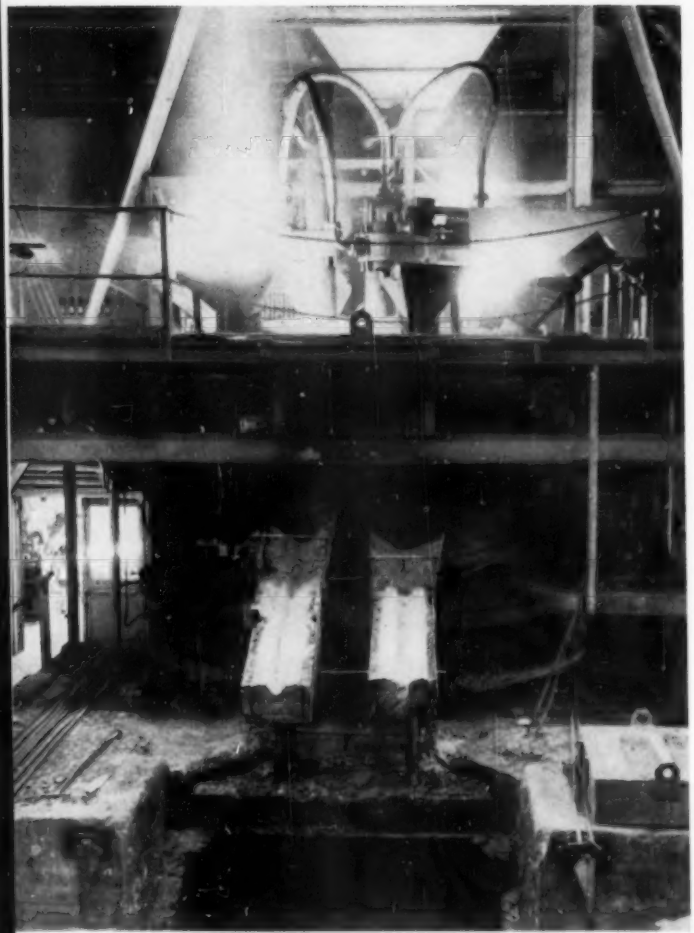


Fig. 3 — Electric Smelting Furnace at Pilot Plant. The slag tap is on the left; the metal tap on the right. After carbon is reduced to proper value (0.2 to 3.5%), the iron is pigged and preferably charged into a refining furnace as "hot metal"

Silicon ranged from 0.10 to 0.15% in the three runs; average analyses are:

Series	C	S
1	2.20	0.06
2	1.52	0.09
3	0.65	0.135

Average slag analysis was 3.0% Fe; minimum was 0.48%.

Up to 50% reduction of iron was achieved in the kiln. Higher reductions in the kiln were not sought, since we were more concerned with maximum production.

For the whole demonstration, 18,000,000 Btu. per ton of metal was used. In the best periods, this figure was as low as 13,000,000 Btu. per ton. Average power consumption for 13 days operation, including "building" of the crucible, was 1561 kw-hr. per ton of metal with a low of under 1100 kw-hr. per ton. Electrode consumption for the whole run averaged 16 lb. per ton of metal. Dust from the kiln was less than 2% of the feed and was returned to the cycle.

Manufacturing costs in the prototype plant were $17 per ton of metal above the cost of ore; this does not include any capital or selling costs.

Capital costs have been estimated for a 600-ton per day plant to be approximately $50 per "annual ton" of iron. This, of course, will vary, depending upon the proposed location.

Summary — As mentioned before, the process is a combination of a rotary kiln and an electric furnace smelter. One significant difference between it and other processes is in the operation of the electric furnace. Instead of the conventional submerged-arc charging method, a "floating charge" technique is used. The charge slides down the furnace sides substantially according to its angle of repose. Thus the partially prereduced and preheated feed material falls directly into the reaction zone at the electrodes, enabling easy control of reduction. Another difference is the kiln operation, which uses fines and controls the carbon (coal) to slightly in excess of the theoretical required for total reduction either in the kiln or the electric reduction furnace. All CO is burned in the kiln to CO_2. Capacity in the kiln is not sacrificed for high metal reduction. Unique process advantages are:

1. No special ore preparation is required. Agglomeration, briquetting, sintering, pelletizing or nodulizing of the ore are unnecessary and not recommended. The process is designed to use fine ores or fine concentrates (including flue dust, mill scale, cast iron borings and shredded light scrap) with no preliminary treatment, other than drying to a constant moisture level.

2. Ores contaminated with titanium, manganese and chromium, or other "impurities" (from the standpoint of conventional blast furnace feed) can be employed directly. This makes available the tremendous deposits of titaniferous magnetites in North America and elsewhere.

3. Bituminous coal, anthracite coal, peat, lignite, or coke can be used as a combined reductant and heat producer.

4. Carbon can be controlled anywhere between 0.2 and 3.5%, readily producing metal for foundry, electric furnace, and openhearth.

5. The process can be developed on a unit basis to the production of 50 tons of iron per day and upward.

High-Alloy Castings . . .

Specifications and Properties

*By ERNEST A. SCHOEFER**

Castings made from corrosion and heat resistant alloys are used under conditions where other materials would be destroyed by the action of the environment. Frequently referred to as stainless steel castings, the multiplicity of grades available is the result of the need to tailor-make alloys for the severe service applications in which the castings are employed. (Q-general, R-general; S22; SS, SGA-g, SGA-h, 5-60)

HIGH-ALLOY CASTINGS are known as corrosion and heat resistant alloys and frequently are grouped under the name, "stainless steel". The distinguishing feature of these castings is that they can serve under conditions where carbon or low-alloy steels would be destroyed, not by the conditions of loading, but by action of the environment. Alloys classed as corrosion resistant are used to resist corrosive attack at temperatures less than 1200° F. Those classed as heat resistant are used where the metal temperature is generally in excess of 1200° F.

All these alloys contain iron, chromium and nickel in various proportions, but with chromium always in excess of 8%. Nickel ranges from under 1% to as high as 68%. Manganese and silicon are present in all the alloys, ranging from about 0.40 to 2.0%. Carbon content is especially important in its influence on corrosion resistance and strength. The corrosion resistant grades are normally very low in carbon, generally under 0.20% and sometimes as low as 0.02%.

In the heat resistant grades, carbon gives high-temperature strength; for this reason, these alloys contain carbon in range of 0.20 to 0.75%. This difference in carbon content is one of the chief distinctions between the corrosion resistant and heat resistant groups. Other elements such as columbium, molybdenum and selenium are added for specific purposes.

While most of the corrosion resistant grades have corresponding wrought stainless steel counterparts, the chemical composition ranges for the cast and wrought alloys differ. For this reason, buyers should use cast-alloy designations for proper identification of castings. The Data Sheet, p. 96-B, gives standard compositions of the Alloy Casting Institute, with outstanding properties and applications for the alloys. The A.C.I. system of nomenclature is used in A.S.T.M. specifications and by many individual producers. The Aircraft Material Specifications group of S.A.E. has adopted these chemical ranges in a number of specifications; they are also used for several specifications of the United States Navy.

High-alloy castings have a somewhat lower modulus of elasticity in tension than steel, varying from about 24,000,000 psi. for the high-nickel grades to 29,000,000 for the chromium-predominant alloys. This compares with 30,000,000 for steel. Density of the alloys is very similar to steel. The specific heat of steel, 0.12 Btu. per lb. per °F., is bracketed by the casting alloy values of 0.11 to 0.14.

Except for the lowest alloy types, CA and HA, none of the high alloys go through the allotropic changes characteristic of carbon and low-alloy

*Executive Vice-President, Alloy Casting Institute, Mineola, N. Y.

steels, upon heating. Thus, the high alloys are not hardenable by heat treatment except for the two grades noted above. For this reason, the heat resistant grades are normally supplied in the as-cast condition. Heat treatment of corrosion resistant grades is for the purpose of maintaining carbides in solution. (Heat resistant grades are designated by initial letter "H", corrosion resistant grades by "C".)

The magnetic properties of high-alloy castings depend on their microstructure. The straight chromium types, CA, CB and CC, HA, HC and HD, are ferritic in structure and ferromagnetic. All the other grades are mainly austenitic, with or without minor amounts of ferrite, and are either weakly magnetic or wholly nonmagnetic. All the high alloys have higher electrical resistance, larger thermal expansion coefficients, and lower thermal conductivity than steel. These properties influence the design of structures for high-temperature service and must also be considered when castings are made part of a composite welded structure.

Fig. 1 — Valve Bodies Made of Type CF-8, Weight About 180 Lb. Each. They are produced six at a time by a multiple centrifugal casting technique

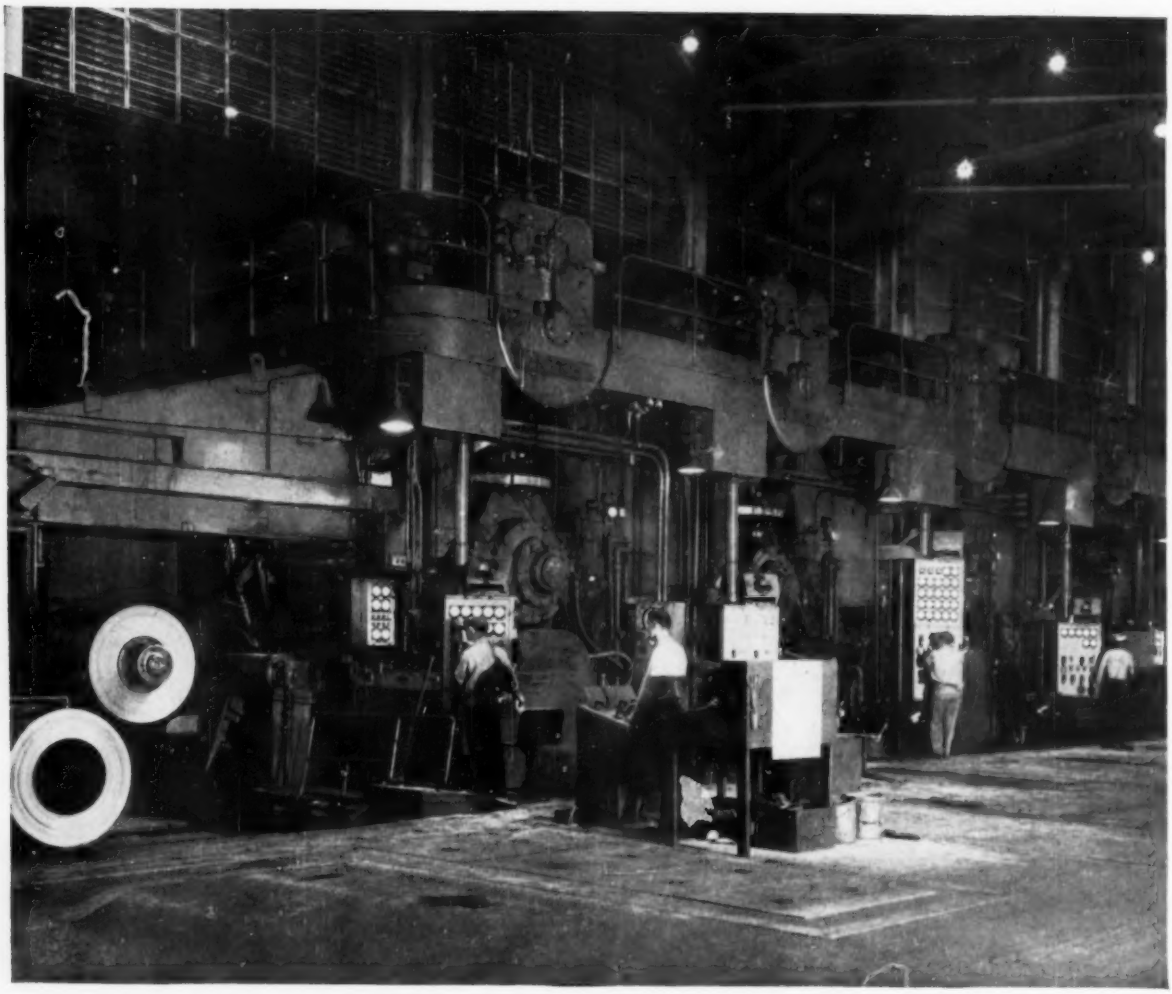
The articles and data sheet which follow on high-alloy castings constitute another in a series of special reports on metallic materials which the editors of *Metal Progress* will present from time to time to help you do a better job in metals engineering.

Contraction of high alloys in going from the liquid to the solid state, and subsequently to room temperature is, in general, greater for high alloys than for steel. Accordingly, the shrinkages allowed by patternmakers for the high-alloy grades are higher than those for steel, and considerably greater than those for gray iron. This means it is important that pattern equipment be specifically designed for high-alloy production if dimensionally accurate castings are to be obtained. Best results are realized when the foundryman is consulted in the early stages of design.

Mechanical Properties

At room temperature, tensile strength of the cast high alloys ranges from 55,000 to 220,000 psi. and hardness from Brinell 130 to 470. Similar wide ranges exist in yield strength, elongation and impact values. With respect to the last characteristic, the wholly austenitic type containing 19% Cr and 9% Ni (grade CF-8), is outstanding in its retention of toughness at subzero temperatures. At −423° F. (the temperature of liquid hydrogen), this alloy has an impact strength of over 50 ft-lb. in comparison to about 75 ft-lb. at room temperature.

In the temperature range where the heat resistant high alloys are used, several factors not usually considered in design of structures at ordinary temperatures have an important bearing on the acceptable design stress. Because the castings operate in the region of plastic rather than elastic strain, the time element is vital. For this reason, the high-temperature mechanical strength is reported in several ways. The first of these is the conventional tensile test, with the load applied at a fairly rapid rate (usually 0.03 in. per min. rate of separation of the gage marks), with values of ultimate strength, yield and elongation given for the various test temperatures. These so-called short-time tests are useful in



Weirton equips cold strip mill with double-poured Ni-hard working rolls

Ni-Hard nickel-chromium cast iron provides hardness of 80 to 82 Shore . . . provides long life, consistently good finish

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For your applications. Ni-Hard alloy possesses the fluidity and freezing range of the cast irons and can be readily cast in all forms and shapes common to the iron and steel foundry. If you'd like specific information concerning its application to your abrasion problem, write Inco. For details on double-poured Ni-Hard rolls, write the fabricator, United Engineering Company.

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Corrosion and Heat Resistant High-Alloy Castings

Standard designations, chemical composition ranges, mechanical properties, corrosion resistance, typical uses and other information which will help in selection of the right alloy. (A-general; SGA-h, 5-60)

A.C.I. Designation	A.I.S.I. Type* or Trade Name	Composition (%, bal. Fe) C	Si Max.	Cr	Ni	Other Elements (a)	Outstanding Properties	Typical Uses
CA-15	410	0.15 max.	1.50	11.5-14	1.0 max.	(b)	For mild corrosion service at ambient temperature. Good atmospheric resistance. Hardenability is Brinell 144 to 400.	Pump casings, bushings and liners, impellers, shafts, turbine blades, stuffing boxes, valve bodies and trim, fittings, furnace burner tips and pilot cones.
CA-40	420	0.20-0.40	1.50	11.5-14	1.0 max.	(b)	Corrosion resistance same as CA-15. Hardenability up to Brinell 500.	Choppers, cutting blades, cylinder liners, pump parts, steam turbine parts, molds, dies.
CB-30	431	0.30 max.	1.00	18-22	2.0 max.	—	Moderately severe service under oxidizing conditions. Resists nitric acid, alkaline solutions, and many organic chemicals. Non-hardenable.	Furnace brackets and hangers, pump parts, rabble arms, tube supports, valve bodies and parts.
CC-50	446	0.50 max.	1.00	26-30	4.0 max.	—	Resists dilute sulphuric acid, mixed nitric and sulphuric acids and oxidizing acids. Magnetic, good machinability.	Bushings, cylinder liners, pump casings and impellers, valve bodies and seats.
CD-4 M Cu	—	0.040 max.	1.00	25-27	4.75-6.00	Mo 1.75-2.25 Cu 2.75-3.25	Hardenable alloy with corrosion resistance equal to CF-8. Harness: Brinell 250, W.Q. from 2000° F.; Brinell 300, aged at 900° F. Double strength of CF-8 and good ductility at Brinell 300.	Valve trim, pumps, fittings, high-pressure parts, gears.
CE-30	312	0.30 max.	2.00	26-30	8-11	—	Useful where castings cannot be heat treated. Resists sulphurous acid and sulphites. Better strength and ductility than CC-50.	Process industry equipment such as digester fittings, fractioning towers, piping, pump bodies and casings, valve bodies and parts.
CF-4	304 L	0.04 max.	2.00	17-21	8-12	—	Similar to CF-8. Useful where castings cannot be heat treated after welding.	Similar to CF-8.
CF-4 M	316 L	0.04 max.	1.50	17-21	9-13	Mo 2-3	Similar to CF-8 M. Useful where castings cannot be heat treated after welding.	Similar to CF-8 M.

A.C.I. Designation	A.I.S.I. Type* or Trade Name	Composition (%, bal. Fe) C	Si Max.	Cr	Ni	Other Elements (a)	Outstanding Properties	Typical Uses
CF-8	304	0.08 max.	2.00	18-21	8-11	—	Resists highly oxidizing conditions such as boiling 65% nitric acids. High impact strength at subzero temperatures.	Autoclaves, blast-furnace bushings, filter press plates, hardware, headers and heating coils, pump parts, spray nozzles, valve parts.
CF-8 C	347	0.08 max.	2.00	18-21	9-12	Cb Cb-Ta (c)	Suitable for field welding. Corrosion resistance similar to CF-8.	Aircraft shroud assemblies, autoclaves, chemical tubing, fittings, jet engine parts, marine fittings.
CF-8 M	316	0.08 max.	1.50	18-21	9-12	Mo 2-3	Increased stability under weak oxidizing conditions. Resists reducing solutions and pitting corrosion in sea water. Used up to 1000° F.	Agitators, evaporator parts, jet engine components, spray nozzles, high-pressure steam valves.
CF-12 M	316	0.12 max.	1.50	18-21	9-12	Mo 2-3	Corrosion resistance not quite as good as CF-8 M, but preferred above 1200° F.	Similar to CF-8 M.
CF-16 F	303	0.16 max.	2.00	18-21	9-12	Mo 1.5 max.; P 0.17 max.; Se 0.2-0.35	Improved machinability; good welding characteristics. Corrosion resistance somewhat inferior to CF-20, but adequate for many purposes.	Bearings, bushings, fittings, pump and machinery parts.
CF-16 Fa	—	0.16 max.	2.00	18-21	9-12	Mo 0.4-0.8 S 0.2-0.4	Similar to CF-16 F.	Similar to CF-16 F.
CF-20	302	0.20 max.	2.00	18-21	8-11	—	Satisfactory in many oxidizing environments. High ductility and good impact strength.	Cylinder liners, pumps, return bends, rolls.
CH-20	309	0.20 max.	2.00	22-26	12-15	—	Not as strong as CE-30 but better ductility; stronger than CF-8 but less ductile. Resists hot dilute sulphuric acid.	Digester fittings, roasting equipment, valves, pump parts.
CK-20	310	0.20 max.	2.00	23-27	19-22	—	Resists dilute sulphuric acid. Good for elevated temperatures.	Digesters, filter press parts, fittings, jet engine parts, pumps valves.
CN-7 M	Carpenter 20	0.07 max.	(d)	18-22	21-31	Mo-Cu (d)	Resists hot concentrated, weakly oxidizing solutions, such as sulphuric acid in addition to severe oxidizing media. Withstands reducing chemicals and chlorides. Nonmagnetic with good machinability. Welds only fair.	Filter parts, heat exchanger parts, pickling rolls, hooks and racks, tanks, valve parts. Parts for rayon spin bath.
HA	—	0.20 max.	1.00	8-10	—	Mo 0.9-1.2	Maximum use temperature: 1300° F. At 1000° F. creep strength is 16,000 psi.; 100-hr. rupture strength is 37,000 psi.; 1000-hr. rupture strength is 27,000 psi. Fan blades for hot gases, trunnion for glass rolls.	
HC	446	0.50 max.	2.00	26-30	4.0 max.	(b)	Maximum use temperature of 1200° F. with moderately heavy loading. At 1600° F. creep strength is 750 psi.; 100-hr. rupture strength is 1700 psi.; 1000-hr. rupture strength is 1300 psi. Used to resist high-sulphur atmospheres when heavy loading is not involved. Used for parts for ore roasting furnaces, such as rabble arms and blades; also for salt pots, grate bars, gas control valves.	
HD	327	0.50 max.	2.00	26-30	4-7	(b)	About same properties as type HC, except somewhat greater strength at elevated temperatures. Useful in high-sulphur atmospheres. At 1600° F. creep strength is 1900 psi., 100-hr. rupture strength is 5000 psi. Uses are similar to HC where more ductility is needed.	
HE	—	0.2-0.5	2.00	26-30	8-11	(b)	Maximum use temperature of 2000° F. Good corrosion resistance and ductility; moderate strength at elevated temperatures. At 1600° F., creep strength is 2000 psi., 100-hr. rupture strength is 5300 psi.	Useful in high-sulphur atmospheres where moderate strength is required; ore roasting furnaces, steel mill furnaces and carrier blades. Used in radiant tubes for coke oven gas.
HF	302 B	0.2-0.4	2.00	19-23	9-12	(b)	Maximum use temperature of 1600° F. Good corrosion resistance in the range 1200 to 1600° F. At 1600° F. creep strength is 3200 psi., 100-hr. rupture strength is 3800 psi.	Used in oil refineries for tube supports and beams; in cement mill parts, ore roasting furnace parts, conveyer belts, heat treating furnace parts and trays. Excellent for many applications not over 1600° F. in air atmosphere.
HH	309	0.2-0.5	2.00	24-28	11-14	N 0.2 max. (b)	Maximum use temperature of 2000° F. High strength and oxidation resistance at elevated temperatures. Depending on composition, the alloy can be partially ferritic or fully austentic. At 1600° F. partially ferritic type has creep strength of 1700 psi., 100-hr. rupture strength is 6400 psi., 1000-hr. rupture strength is 3800 psi.; at 1600° F. fully austenitic type has creep strength of 4000 psi., 100-hr. rupture strength of 7500 psi., 1000-hr. rupture strength of 4700 psi. Used for tube supports and beams in oil refineries, ore roasting furnace parts, lead pans and heat treating parts. Major alloy for normalizing, malleabilizing and roller hearth furnace parts.	

A.C.I. Designation	A.I.S.I. Type* or Trade Name	Composition (%, bal. Fe) C	Si Max.	Cr	Ni	Other Elements (a)	Outstanding Properties	Typical Uses
HI	—	0.2-0.5	2.00	26-30	14-18	(b)	Maximum use temperature of 2150° F. At 1600° F. creep strength is 3600 psi., 100-hr. rupture strength is 7500 psi., 1000-hr. rupture strength is 4800 psi. Used for cast retorts for magnesium production.	
HK	310	0.2-0.6	2.00	24-28	18-22	(b)	Maximum use temperature of 2100° F. Resists hot gas corrosion better than type HH. Not recommended for high-sulphur atmospheres or where severe thermal shock is involved. At 1600° F. creep strength is 4200 psi., 100-hr. rupture strength is 7800 psi., 1000-hr. rupture strength is 5000 psi. Used where high creep strength is needed; furnace parts, chains and radiant tubes.	
HL	—	0.2-0.6	2.00	28-32	18-22	(b)	Maximum use temperature of 2100 to 2200° F. Good corrosion resistance in sulphur atmospheres. At 1600° F. creep strength is 4300 psi., 100-hr. rupture strength is 9200 psi. Used for gas dissociation equipment, fixtures and radiant tubes.	
HN	—	0.2-0.5	2.00	19-23	23-27	(b)	Good high-temperature strength and corrosion resistance in chemically reactive media.	Employed for brazing fixtures for use up to 2060° F. Similar to HT, with higher strength.
HT	—	0.35-0.75	2.50	13-17	33-37	(b)	Maximum use temperature of 2000° F. Excellent service life where subject to rapid heating and cooling. At 1600° F. creep strength is 4500 psi., 100-hr. rupture strength is 8500 psi., 1000-hr. rupture strength is 7000 psi.	Widely used for heat treating furnace parts such as rails, rolls, disks, chains, boxes, pots, trays, and fixtures subject to cyclic heating. Also used for glass rolls, enameling racks, radiant heater tubes, conveyers and retorts.
HU	—	0.35-0.75	2.50	17-21	37-41	(b)	Excellent hot strength and corrosion resistance at high temperatures. At 1600° F. creep strength is 5000 psi., 100-hr. rupture strength is 6000 psi.	Similar to HT. Used where improved resistance to hot gas corrosion is required. Thermal fatigue resistance and strength are superior to HT. Widely used for trays.
HW	—	0.35-0.75	2.50	10-14	58-62	(b)	Maximum use temperature 2050° F. in oxidizing atmospheres and 1900° F. in reducing atmospheres. Excellent for severe service at high temperatures involving cyclic heating or thermal shock. At 1600° F. creep strength is 3000 psi., 100-hr. rupture strength is 6000 psi., 1000-hr. rupture strength is 4500 psi. Used for hearths, muffles, retorts, trays, boxes, burner parts enameling fixtures, quenching fixtures, and molten lead containers.	
HX	—	0.35-0.75	2.50	15-19	64-68	(b)	Maximum use temperature same as HW, but considerably better than HW in resistance to reducing gases containing sulphur at 1800° F. At 1600° F. creep strength is 3200 psi., 100-hr. rupture strength is 6700 psi., 1000-hr. rupture strength is 4000 psi. Used on contact with tempering and cyaniding salts. Same applications as HW, but used where improved resistance to hot gas corrosion is required. Also for applications requiring high resistance to thermal fatigue such as muffles, certain retorts and heating elements.	

Special Nickel-Base Alloys† for Corrosion Resistance Applications

—	Hastelloy B Chlorimet 2	—	—	—	65	30 Mo	Little or no resistance to oxidizing media but used under highly reducing conditions. Difficult to machine.	Severe reducing services, such as hydrochloric acid. Also, for phosphoric acid, sulphuric acid and caustics.
—	Hastelloy C Chlorimet 3	—	—	17	65	17 Mo	Resists highly reducing solutions but not sensitive to oxidizing agents present in a mixed acid or which might appear as a contaminant. Not as resistant to highly oxidizing conditions as iron-base alloys.	Used in severe reducing services, resists oxidizing bleach solutions such as chlorine dioxide, sodium and calcium hypochlorites. Not subject to pitting due to chlorides.
—	Monel	—	—	—	65	30 Cu	Good for reducing solutions; not resistant to general oxidizing conditions.	Used in hydrofluoric and hydrochloric acids and sea water.
—	Nickel	—	—	—	95	—	Resists caustics and pitting in chloride environments; little or no protection against oxidation.	Primarily used for handling caustic solutions dry hydrogen chloride and chlorine gas.
—	Inconel	—	—	14	78	—	Resists mildly oxidizing solutions.	Applications similar to nickel and Monel but can be used with mildly oxidizing solutions.

†Only predominant alloying elements listed.

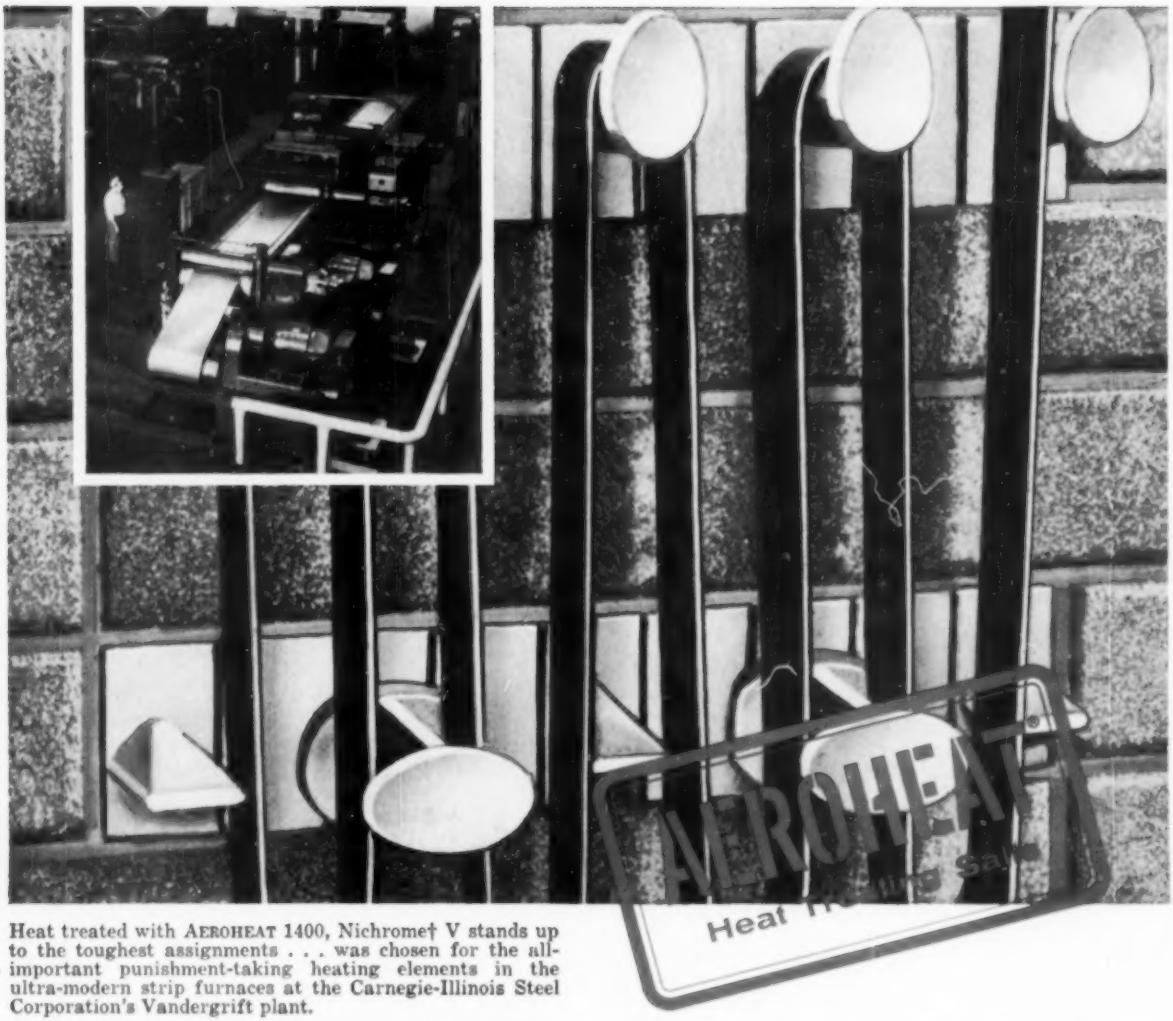
*A.I.S.I wrought alloy type numbers are listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast alloy chemical composition ranges are not the same as the wrought alloys, buyers should use cast alloy designations for proper identification of castings. Most of the standard grades listed are covered for general applications by American Society for Testing Materials Specifications A 296-49 T and A 297-49T. A.S.T.M. Specifications A 217-49 T, A 351-52 T, A 362-52 T, B 190-50 and B 207-50 also apply to some of the grades.

(a) Manganese 1.00 max. in CA-15, CA-40, CB-30, CC-50 and CD-4 M Cu. 1.50 max. in all other C alloys; 0.35-0.65 in HA; 1.00 max. in HC; 1.50 max. in HD; 2.00 max. in all other H alloys. Phosphorus and sulphur each 0.04 max. in all alloys except CF-16 F, wherein P is 0.17 max., and in CF-16 Fa, wherein S is 0.20-0.40.

(b) Molybdenum 0.5 max. (not intentionally added).

(c) Columbium 8 × C min. 1.00 max.; Cb+Ta 10 × C min., 1.35 max.

(d) Proprietary alloys contain varying amounts of Si, Mo and Cu.



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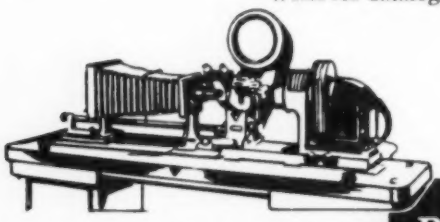

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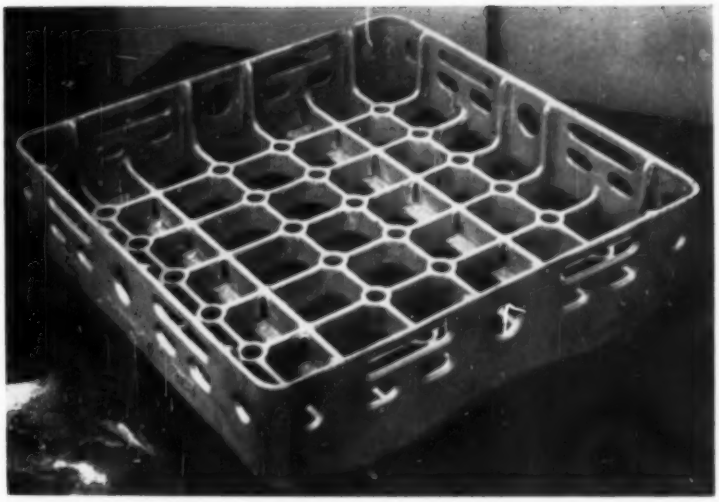

Fig. 2 – Heat Treating Tray Cast From Type HU for Use in Gas-Fired Annealing Furnace at 1750° F. The tray carries about 270 lb. of small gear forgings

indicating the maximum stress that can be withstood without failure for a short period of time. They apply to a short-lived structure, or to a momentary overload of a structure intended for long service. These data, however, are not a reliable guide to the comparative strength of different alloy grades for long periods of time.

For long service, the designer must consider the rate of deformation of a loaded part at constant temperature, or the life that can be obtained before fracture at some particular stress level. To satisfy the designer's interest in deformation, values are reported at different temperatures for the "limiting creep stress". This is the stress on the original cross section resulting from a constantly applied load that will produce a constant rate of strain or "secondary creep" – values are frequently given for a stress which will produce a creep rate of 0.0001% per hr. Where fracture time is the criterion, data are reported for stress to rupture in 10 hr., 100 hr., 1000 hr. or even longer times.

A design stress frequently suggested is 50% of the limiting creep stress at the maximum operating temperature. Such a value should be applied only under conditions of direct axial static loading and with essentially uniform temperatures. Where impact loading or rapid temperature cycles are involved, a considerably lower percentage of the limiting creep stress should be used. In the selection of design stresses, safety factors should be higher if the parts are inaccessible, nonuniformly loaded, or of complex design. They may be lower if the parts are accessible for replacement, fully supported or rotating, and of simple design with little or no thermal gradient.

The corrosion resistant alloys are, in general, resistant to oxidizing media. The more strongly oxidizing the corrosive, the higher the alloy content needed. Alloys containing nickel, molybdenum and copper resist reducing or weakly oxidizing media. The article by Mr. Bryan on p. 102 gives data on selection of alloys for corrosive service. The austenitic alloys are heat treated at about 2000° F. to get all the carbon in solution. Then they are rapidly quenched to avoid reprecipitation of chromium carbides.

Corrosion resistance and other service conditions should be considered in the selection of alloys for high-temperature use, as is discussed by Mr. Miller in an article on p. 98. Here, the resistance to corrosion generally refers to gaseous rather than aqueous media. Chromium gives resistance to oxidation by air and furnace gases. Silicon promotes resistance to oxidation and also helps to prevent carburization in carburizing atmospheres. Nickel is important in resisting carbon penetration but reduces resistance to sulphur-bearing gases. The heat resistant alloys are also used to contain molten metals and salts; the various grades show different degrees of resistance.

An engineer confronted with a condition of corrosive or high-temperature operation must select a material of construction that will give an economic life in service. He must then design his structure within the limits of the physical and mechanical properties of the material selected. Heat and corrosion resistant high-alloy castings provide the designer with combinations of properties that answer many requirements more economically than other materials.

High-Alloy Castings . . .

Selection of Alloys for Heat Resistant Service

*By R. A. MILLER**

Emphasis should be on minimum cost per operating hour, not on first cost alone. Proper choice of an alloy to do a given job depends upon several considerations. Among these are hot strength, resistance to hot gases, hot and cold ductility, resistance to carburization and thermal fatigue. (Q-general, 17-57; SGA-h, SS, 5-60)

How do you select the right casting for a particular, and sometimes unique, high-temperature application? The problem posed by this question often requires difficult compromises. We consider the range of 1200 to 2200° F. as the area where heat resistant castings should be applied. The data sheet, p. 96-B, gives the chemistry and properties of many widely used heat resistant alloys. The heat resistant groups are designated with the initial letter "H". The alloys range from about 10 to 30% Cr and from 0 to 70% Ni.

The first requirement in the selection of the right casting is knowledge of the properties of the alloys. Physical properties which must be considered are thermal expansion, thermal conductivity and electrical resistivity. Significant mechanical properties are room-temperature strength and ductility, elevated-temperature strength and thermal fatigue resistance. Other factors are castability, weldability, machinability and surface stability to the operating environment. We follow a step-like sequence in selecting an alloy casting for a set of operating conditions. This article is built around our experience in applying this logic.

Operating Temperature

The first step considers the maximum temperature of operation of the casting. This is not necessarily the furnace temperature, as recorded on the controller, but means the actual temperature reached by the casting when in use. Frequently, a casting will operate at a temperature much above the furnace control temperature. An example: radiant tubes for heating a con-

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Table 1 – Typical Environments in Which High-Alloy Castings Are Used in Order of Increasing Severity

A. Air
B. Combustion Products
   1. No sulphur – CO, CO_2, H_2O, N_2, O_2
   2. Sulphur – CO, CO_2, H_2O, O_2, N_2, SO_2 or H_2S
C. Reducing
   1. Exothermic – CO, CO_2, H_2, H_2O, N_2
   2. Endothermic – CO, H_2, N_2
   3. Cracked ammonia or hydrogen – N_2, H_2
D. Carburizing and carbo-nitriding – H_2, N_2, CH_4 (or other hydrocarbons)
E. Liquids
   1. Metals – Pb
   2. Salts – neutral, cyanide

trolled-atmosphere furnace. Here the temperature of the tube wall may be as much as 300° F. above the normal operating temperature of the furnace.

Also, there are conditions where the casting may operate at a temperature considerably below the operating temperature of the equipment. An example is the alloy-brick retaining segments in a cement kiln. Although the temperature of the clinker flowing over the segments may approach 3000° F., the temperature of the casting seldom exceeds 2000° F.

Operating Environment

The second step considers the atmosphere in which the alloy casting is to be used. Table I gives the most common environments in heat treating operations, listed in order of increasing severity on the alloy. For furnace environments A, B, and C, any of the alloys can be used up to their maximum recommended operating temperature. However, the maximum operating temperature for many castings must be lowered if they are to be used in furnace environments D and E.

Several exceptions should be noted. For atmospheres, either oxidizing or reducing, which contain appreciable amounts of sulphur, the high-chromium low-nickel grades, HC, HD or HE, should be considered. The HE grade is the one most widely used to combat sulphur conditions. Grades which are most frequently used in contact with liquid metals are HH and HT. In liquid carburizing salts, the HT grade is the most generally used alloy. Neutral salts are very corrosive and generally cause intergranular oxidation. Selection of an alloy for neutral salt service should be referred to the foundry for recommendation because in many cases it is necessary to sacrifice some high-temperature strength by producing an alloy to a low-carbon specification to resist intergranular attack.

Operating Conditions

The third step considers the service condition under which the alloy will operate. Generally, this can be broken down into three categories:

1. Continuous or semicontinuous with respect to temperature and atmosphere.
2. Discontinuous
   (*a*) Slow heating and cooling
   (*b*) Rapid heating or cooling
   (*c*) Quenching
3. Mechanical abuse

A semicontinuous operation is defined as one in which the part is seldom cooled to room temperature, but it may be subjected to fluctuating temperatures. An example: a rotary carburizing retort operating continuously during the week but idled at a somewhat lower temperature over the weekend. Additional temperature fluctuations occur when a cold load of work is charged into the hot retort.

Discontinuous conditions are those in which the casting is cycling between room temperature and operating temperature. These occur in equipment operating on a one-shift basis, or in operations where the casting accompanies the work in and out of the furnace. Here an important factor called thermal fatigue enters the picture. Thermal fatigue damage occurs when thermal stresses, created by differential temperatures, exceed the yield point of the alloy. The high thermal expansion with low thermal conductivity, and relatively low yield point of the austenitic heat resistant alloys accentuates this problem. Increasing the amount of nickel in the alloy increases resistance to thermal fatigue failure. In instances where the problem is severe, such as direct quenching, additional elements such as columbium and molybdenum improve thermal fatigue properties very markedly, particularly where carburizing conditions are involved.

Let's consider some other examples of how service considerations influence alloy selection: A rotary carburizing retort operating under continuous conditions may be made from HT alloy. However, if it operates under semicontinuous or discontinuous conditions, it should be made from HW alloy. A furnace rail made from HT alloy for use in a carburizing furnace may last five years. However, a tray or fixture made from the

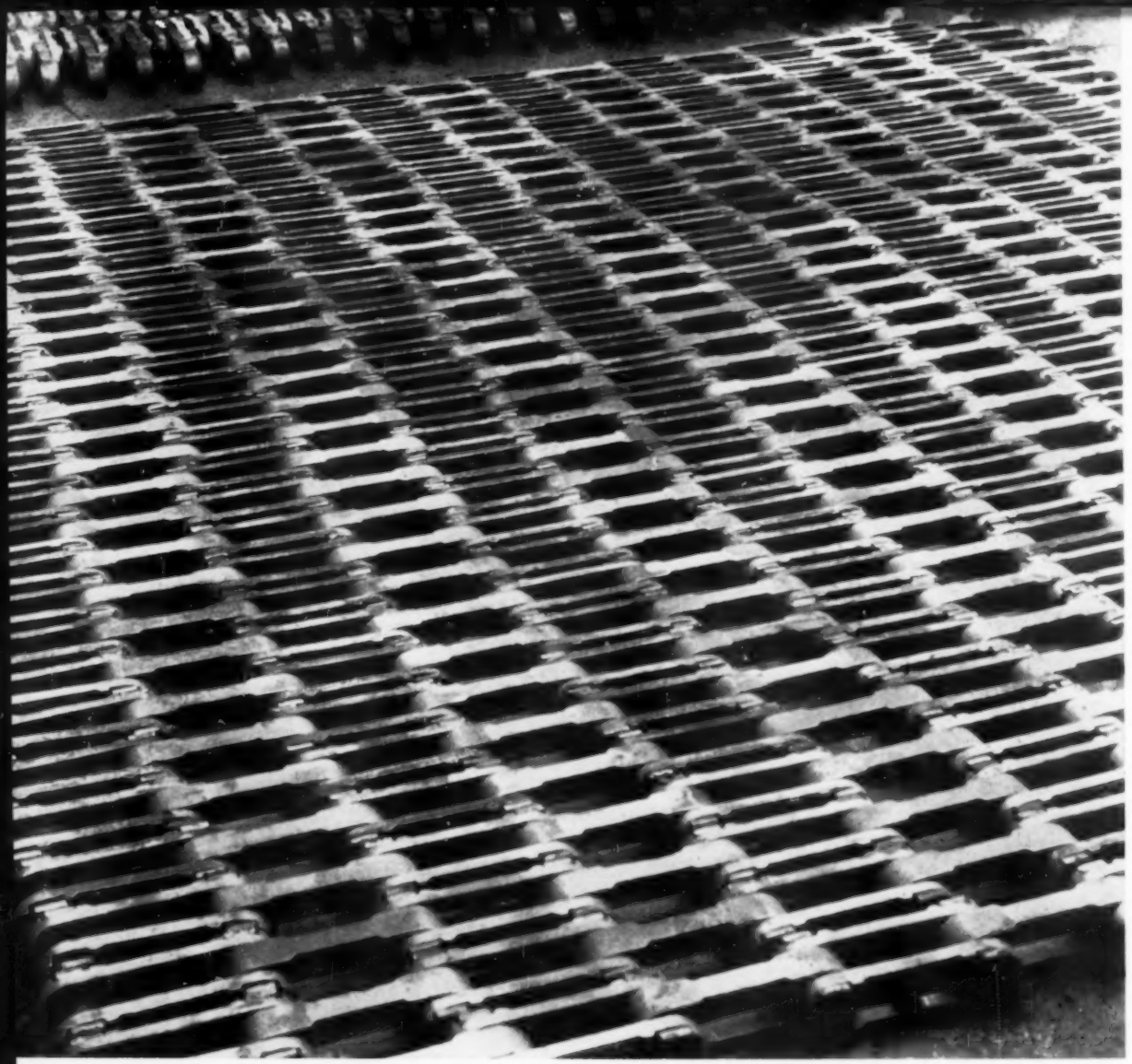

Fig. 1 – Rivetless Conveyer Chain (Front) and Serrated Chain (Rear) Used To Carry Axle Shafts Through Hardening Furnace. The chain which is used up to 1800° F. is made from Type HT when thermal shock is a factor and Type HH when operating under constant temperature

same alloy for use in this furnace might last only six months to one year, when employed in a quench.

The final narrowing in the choice of alloys usually occurs when strength and design requirements are considered. If service requires a high-strength alloy, choice narrows rapidly. If, on the other hand, strength required is low, several alloys may be in the picture. Then, selection becomes largely a matter of cost.

Certainly, in today's economy, cost is an important factor. However, the cost of heat resistant castings should be considered on the basis of units of production, whether it be operating hours, tons per hour, or some other acceptable measurement, rather than strictly on first cost basis. Maintenance and downtime costs must also be included. Even though alloy A may cost 50% more than alloy B originally, if it lasts twice as long in service, it will be considerably cheaper in the long run.

Design Considerations

The most carefully selected alloy will not perform satisfactorily if cast into a poorly designed shape. Although detailed design considerations are beyond the scope of this paper, three simple rules will be mentioned. The most important is

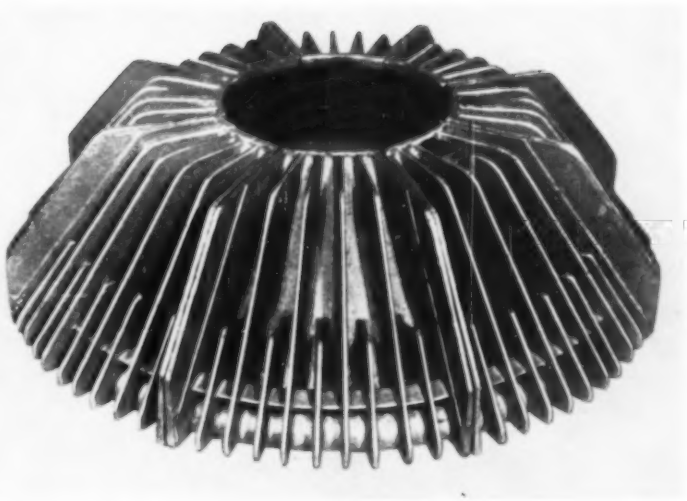

Fig. 2 – Oil or Gas Burner Deflector for Use up to 2000° F. Is Produced From HK Alloy Castings. Some 30 in. in diameter, it is assembled by welding without machining the faces

the thermal gradient pattern to which the casting will be subjected. Rigid designs will distort or crack under conditions of large or fluctuating heat gradients. The second factor: the design used should permit the foundry to produce a high-quality casting. All the alloys are readily castable but some are characterized by high shrinkage. The patternmaker's allowance for shrinkage is 9/32 in. per ft. Another consideration in design is the mechanical loading which the casting must bear. All alloys used for high-temperature castings can be welded. It is important for the designer to remember this. Frequently, it is better to produce a complex casting by making several simple components, then weld these into the final part.

Practice

Here are some examples of alloy selection following the procedures discussed above:

Example 1 – A continuous carburizing furnace contains radiant tubes for heating, rails and pier caps, trays, and fixtures. Which alloys should be used for the various parts? Operating temperature is 1700° F., atmosphere is endothermic, enriched with methane. Trays are heavily loaded and subjected to an oil quench.

Step 1 – All alloys, except HF, will withstand this temperature.

Step 2 – The higher nickel alloys are required because of atmosphere used. This means alloys in the series HK to HX.

Step 3 – Thermal fatigue is severe for trays and possibly the first radiant tubes which must heat the tray load. For rest of parts, it is variable, but mild. Radiant tube temperature may be 1900 to 2000° F., in preheat area, and 1750° F., in diffusion zone. High strength is needed in trays and tubes.

Selections: Trays: Alloy HT or HU, with or without columbium, for strength and thermal fatigue resistance. Tubes: HK or HL in preheat zone for strength and temperature resistance and HK or HT in balance of furnace for carburization resistance, long life, and lower cost. Rails, pier caps, etc.: Alloy HT for temperature resistance, high strength, carburization resistance and long life.

Example 2 – A cement kiln contains firebrick retaining segments on the discharge end and a feed pipe. It may also contain dampers to regulate draft through the kiln. Temperature at discharge end, next to burner, will vary from 1600 to 2000° F. Operations are continuous and there are no significant thermal fatigue problems. Atmosphere is a mixture of air and fuel combustion gases.

Selections, after following the steps, are: Alloy HH for the discharge and segments, and HF for the other parts.

Example 3 – Wire is heat treated using a double lead, patenting process in which the wire is drawn through lead contained in a pan at 1600 to 1650° F. Pans are cast iron and fail in about 21 days by oxidation and deformation.

Step 1 – All alloys except HF will withstand this temperature; alloys HH and HT are most frequently specified for liquid lead service.

Step 2 – Although loading is heavy, temperature is practically continuous. Alloy selection is HH. Service records shows that pans made from this alloy give over 500 days of service.

High-Alloy Castings . . .

Selection of Alloys for Corrosion Resistant Service

*By W. T. BRYAN**

The corrosive environment should be studied for oxidizing or reducing characteristics, temperature, or influence of contaminants. Other factors include mechanical properties and metallurgical structure. (Q-general, R-general, 17-57; SGA-g, SS, Ni, 5-60)

CASTINGS are made of corrosion resistant alloys for the same reasons that other metals are used in the cast form: First is the relative ease and economy of getting integral components of complex shape. Second, the casting process gives efficient distribution of metal for optimum strength-to-weight ratio and rigidity. Frequently, it is easier to obtain castings in a small quantity with a specific analysis than it is to get the same composition in rolled or forged products. Also, certain useful compositions cannot be successfully rolled or forged.

The first consideration in selecting an alloy is a knowledge of the characteristics of the corrosive environment. Usual classifications are oxidizing, neutral, or reducing. However, there are many other factors such as concentration, temperature, aeration, velocity, and, particularly, contamination of the medium. It is the exception to have a pure corrodent in process applications.

Stainless steels are corrosion resistant because of the phenomenon of passivation which results in very low rates of corrosion in many solutions which rapidly attack ordinary steels. Chromium imparts passivity to ferrous alloys when present in amounts more than about 11%, particularly if conditions are strongly oxidizing. Corrosion resistance improves as chromium content increases beyond the minimum required for passivity. Addition of nickel to iron-chromium alloys improves ductility and impact strength. Resistance to corrosion by neutral chloride solutions and weakly oxidizing acids increases in proportion to nickel content. Addition of molybdenum increases resistance to attack by pitting chloride solutions. It also extends the range of passivity in solutions of low oxidizing characteristics. In all iron-chromium-nickel stainless alloys, the lower the carbon content, the better the corrosion resistance.

The corrosion resistant high-alloy castings are designated with the initial letter "C" in the Data Sheet on page 96-B. They are referred to as iron-base and nickel-base, with the former representing probably 95% of production because of their almost universal application and lower cost.

Iron-Base Alloys

The chromium Type CA-15 alloy, containing 11.5 to 14% Cr, has a martensitic structure and thus may be heat treated to achieve hardness where wear is involved. It is used widely for trim in carbon steel valves, for pumps to handle acid mine water involving abrasives, and in paper mill applications where wear is equally as important as corrosion resistance. Type CB-30 alloy, containing 18 to 22% Cr, has a ferritic structure and thus cannot be heat treated to gain hardness. However, its higher chromium content

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Fig. 1 – This Mixer, Used in a Highly Corrosive Oxidizing Solution, Is Cast of a High-Molybdenum Type CF-8 M Alloy

allows a slightly higher range of acid concentration and temperature.

The iron-chromium-nickel alloys have found wide acceptance and constitute about 60% of the total production of cast high alloys. They are generally referred to as being austenitic or nonmagnetic. However, the balance here is fairly narrow; they may be slightly magnetic depending upon the chemistry of the heat or compensating effects of various alloying elements. The most popular alloys of this type are CF-8 and CF-8 M. Their nominal composition is 18% Cr and 8% Ni, with or without 2.5% Mo. Carbon is maintained at 0.08% max.

Heat Treatment

The optimum corrosion resistance of these 18-8 grades of stainless steel, which are essentially austenitic, is obtained by heating in the range of 1950 to 2050° F., and then quenching in water, oil or air to insure complete solution of carbides. Water is generally the accepted quenching medium; air is used only on relatively thin sections. Holding time at temperature will vary with thickness of the casting section, but should be long enough to heat all sections uniformly throughout. This process is known as solution quenching. If it is not done properly, or if the alloy is exposed in the range of 800 to 1600° F. after solution quenching, complex chromium carbides may re-form preferentially at grain boundaries. These carbides are attacked selectively in oxidizing solutions and will in time lead to failure by intergranular corrosion.

The extra low-carbon grades, CF-4 and CF-4 M, which contain 0.040% C max., are made in quantity for applications where heat treatment is impractical or fabrication by welding is required after machining. The columbium-modified grade of 18-8, known as CF-8 C, is produced for special applications. After proper solution quenching of this grade, if heating takes place in the critical range 800 to 1600° F. (particularly 1050 to 1200° F.), carbides will precipitate preferentially as columbium carbides instead of chromium carbides, and corrosion resistance is not impaired.

The accepted test for evaluation of proper heat treatment is ten days in boiling 65% nitric acid. Maximum corrosion rate permitted in the test is 30 mils per year. Recently, a rapid qualitative etching test using oxalic acid has been developed for screening purposes. These tests are described in A.S.T.M. Specifications A 262-

55 T and A 393-55 T, respectively. Failure due to intergranular corrosion occurs less frequently than it did 15 years ago. This is attributed to the use of gaseous oxygen in removing carbon during melting, modern heat treating equipment, and more know-how in the casting industry.

Same as with wrought grades, other special analyses are available which contain selenium or sulphur (about 0.30%) to improve machinability. These are not widely used. The ability to machine the conventional CF-8 alloy has advanced to the point where the slight assistance from these elements is generally not needed.

Iron-Chromium-Molybdenum Alloys

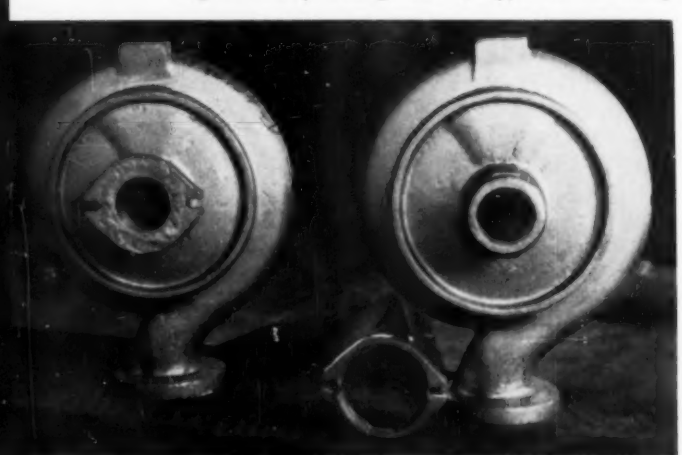
Alloys of the CF-8 M type are sufficiently important to deserve more comment. They are a modified CF-8 type to which molybdenum is added, in the range of 2.0 to 3.0%, to enhance the general corrosion resistance. Their passivity is more stable under weakly oxidizing conditions. They have good resistance to corrosive media, such as sulphurous and acetic acids, and they are more resistant to pitting when exposed to mild chlorides. These alloys are not recommended for use in sea water or severe chloride.

Structure of these alloys is essentially austenitic, with a small amount of ferrite (15 to 20%) distributed throughout the matrix in the form of discontinuous pools. When heated in the range 800 to 1600° F., these pools provide a preferred location for carbides to precipitate. This tends to reduce the susceptibility to intergranular corrosion caused by precipitation of carbides at the austenite grain boundaries.

The amount of ferrite decreases as the carbon content increases. Thus, the low-carbon grade is more strongly magnetic than the higher carbon grade. The elements chromium, molybdenum, and silicon promote the formation of ferrite (magnetic), whereas carbon, nickel, and manganese favor the formation of austenite (nonmagnetic). It is inconsistent to specify the extra low-carbon grade (0.04% C max.) and at the same time request that the castings be completely nonmagnetic. This can be done but it requires 12 to 15% nickel instead of 9 to 12%.

The equivalent wrought grade (Type 304 L normally contains about 13% Ni. It is intentionally made fully austenitic, or nonmagnetic, to get improved rolling and forging characteristics. However, there are advantages of the partially ferritic cast structure, such as increased corrosion resistance under certain conditions, greater strength, and improved weldability.

Fig. 2 – Pump Casings Cast of Type CN-7 M Alloy



Alloys With Higher Nickel

So far we have discussed only the iron-chromium and iron-chromium-nickel alloys, and while these are widely used, there are many severe services where they are unsatisfactory. This resulted in the development of the iron-nickel-chromium grades in which nickel is present in amounts greater than chromium. Most important is alloy CN-7 M with a nominal composition of 28% Ni, 18% Cr, 3% Cu, 2.5% Mo and 0.07% C max. In effect, 20% Ni and 3% Cu have been added to the CF-8 M type alloy. This gives greatly improved resistance to hot concentrated, weakly oxidizing solutions such as sulphuric acid and also improves its resistance to severe oxidizing media. Alloys of this type will withstand all concentrations of sulphuric acid up to 150° F., and many up to 176° F. They are widely used in nitric-hydrofluoric pickling solutions, phosphoric acid, cold dilute hydrochloric acid, hot acetic acid, strong hot caustic solutions, brines, and many complex plating solutions and rayon spin baths.

It is easier to define the conditions for which these higher nickel alloys are not satisfactory. Generally, they involve unstable chlorides. The influence of contaminants is one of the most important considerations in selecting an alloy for a particular process application. Ferric chloride in relatively small amounts, for example, will cause concentration cell corrosion and pitting even though this salt is not added intentionally. A build-up of corrosion products in a chloride solution may increase the iron concentration to a sufficient degree to be destructive.

Thus, chlorine salts, unstable chlorinated organic compounds, or wet chlorine gas cannot be handled by any of the iron-base alloys previously discussed. This creates a need for the special nickel-base alloys shown in the lower part of the Data Sheet (p. 96-B).

There are five proprietary nickel-base alloys. Although they are expensive and are produced in relatively small quantities, they fill the gap in the corrosion resistant series. The first is a 65% Ni, 30% Mo composition useful under highly reducing conditions, such as hot concentrated hydrochloric and hydrofluoric acids, and also in severe applications involving phosphoric and sulphuric acids and caustics. This alloy does not contain chromium and thus has little or no resistance to oxidizing media. It is a very complex alloy and difficult to machine.

One of the most important alloys in this series is the 65% Ni, 17% Cr, 17% Mo composition. Like the alloy above, it may be used under very severe reducing conditions but is not sensitive to oxidizing agents present in a mixed acid or which might appear as a contaminant. In a sense it is a superalloy in that it will resist bleach solutions such as chlorine dioxide, sodium and calcium hypochlorites. In addition, it is not subject to pitting when used to handle solutions contaminated with ferric, cupric or mercuric chlorides and chlorinated organic compounds, such as chloro-acetic acid. While this nickel-base alloy is serviceable for the unusual corrosive conditions, generally speaking, it is not as resistant as the iron-base austenitic alloys to highly oxidizing conditions, such as nitric and mixed acids. It's similar to its sister alloy, without chromium (noted above), in that it is expensive and is difficult to machine.

The three remaining alloys in this series are: Monel, nickel and Inconel. Monel contains 65% Ni and 30% Cu and is used exclusively for reducing conditions such as hydrofluoric acid, hydrochloric acid and sea water. It is not resistant to general oxidizing conditions.

Pure nickel castings contain about 5% total of silicon, manganese, carbon and iron. However, these elements do not destroy the corrosion resistance and are required for the casting process. Primary use of nickel castings is in handling caustic solutions, dry hydrogen chloride and chlorine gas. Nickel-base alloys are similar to the copper-base alloys in that they are not subject to pitting in chloride environments; however, they do not have the broad base of corrosion resistance typical of the iron-chromium-nickel alloys because they do not protect against oxidation. Inconel contains about 78% Ni and 14% Cr. It generally has the same uses as Monel and pure nickel. However, its chromium content enables it to resist mildly oxidizing conditions.

Fig. 3 – Cast of Type CE Alloy, This Unit Weighs 900 Lb. and Must Resist Heat and Corrosion of Hot Sulphite Liquor

The design engineer has an important role in prolonging the life of equipment in corrosion services. One of the first factors he should consider is wall thickness. The rule is often followed that it should be twice the thickness needed to give the desired life. For example, if a ten-year life is required and the best estimate is that corrosion will penetrate ⅛ in. in this period, then the minimum thickness should be ¼ in. For the average size casting, this is the minimum wall for castability.

All of the alloys discussed are readily welded and an increasing number of assemblies involving designs too difficult to produce as integral castings are being made by welding component castings. A sound casting, free of internal shrinkage, is the best insurance that the service life predicted from corrosion test data will be realized. Areas of low density will result in accelerated localized attack. Thus, on new designs it is important that the designer consult with a qualified foundry and corrosion engineer.

The user of corrosion resistant castings should realize that there is no well-defined shortcut to the selection of the exact alloy – particularly for the more difficult applications. After the conditions have been studied, giving consideration to concentration, temperature, and other factors, such as contaminants in the corrosive solutions, it is often wise to make in-plant tests of a select number of alloys.

Resistance Welded Tube Joints in Heat Exchangers

*By J. J. MUELLER**

Resistance welded tube joints, metallurgically sound, uniform, and capable of resisting severe thermal shock cycling, have been produced in Inconel, stainless steel, and several other nickel-base alloys. Operation skill and workload are not taxed in this automatic process. (K3; SS, Ni-b, 4-60)

THE HEAT EXCHANGER has to operate at a much higher level of efficiency than in the past. In addition, it must provide trouble-free service for much longer periods at higher temperatures and in more corrosive environments. This has placed more stringent requirements on the tube-to-tube sheet joints. These joints have been a major trouble spot.

Meets New Demands – Fusion welding techniques have been modified and refined to provide sound and serviceable weld joints to meet these new demands. The inert-gas-shielded tungsten-arc process has been of great value. However, in many instances, because of the inherent deficiencies of many fusion weld structures, trouble-free operation is not possible. The metallurgical deterioration associated with the fusion process manifests itself in lower impact and fatigue strengths, and in segregation and constituent precipitation which aggravate the corrosion problem. In addition, high-order locked-in stresses often develop and may cause cracking and distortion in the as-welded condition or during stress-relieving treatments.

Resistance welded tube joints, consistently strong, leakproof and resistant to severe thermal shock cycling, have been produced. Weld bonds, typical of the pressure-type weld and also of the recrystallization-type, have been made in stainless steels, Ineonel, and other nickel-base alloys. The automatic resistance welding process is also desirable because operator skill and endurance are not taxed.

Methods of Development – Initial approach involved tube and tube-sheet joints of the simplest type. Tube entrance in the tube sheet was drilled and reamed to size. The tube ends were then squared off. Because the preparation of the components was simple, several methods were tried based on this configuration.

Tube welds made with a sharply tapered electrode, shown in Fig. 1, left, were inconsistent. The bonds were of the nugget type and there was a tendency for the tube wall to overheat, rupture, and expel molten metal. Sufficient cooling was not provided by the relatively thin electrode, and since the tube diameters were small, this could not be overcome. The binding of the electrode in the tube could not be eliminated.

Use of a flat-end electrode having a pilot-type bore-cooling plug, shown in Fig. 1, right, produced a satisfactory nugget in the tube-sheet body. By proper selection of electrode materials and welding cycle, the position of the nugget was controlled reasonably well. The results were more consistent than those obtained with the tapered electrode but the nuggets had a tendency to crack and void formations developed. Leak-free joints were not obtained.

Several other attempts to weld tubing having a simple joint design proved impractical because of mechanical or electrical limitations. Next, a more complicated joint design was used, involving a flanged tube end (produced by alternate annealing and die forming operations). The tube sheet surface was machined at the tube entrance to form a ring projection. The arrangement for

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Fig. 1 – Schematic Drawing of Resistance Welded Tube Joints. Initial approach involved a tapered electrode (left) and a piloted flat-end electrode (right). Arrows show current's path

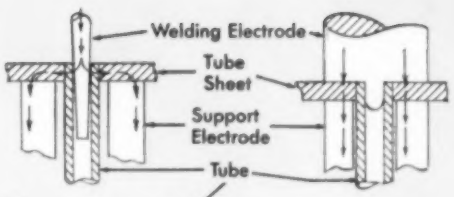


Fig. 2 – Schematic Drawing of Projection Welded Tube Joint

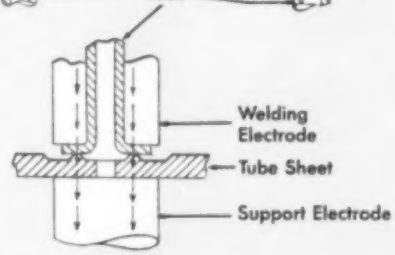
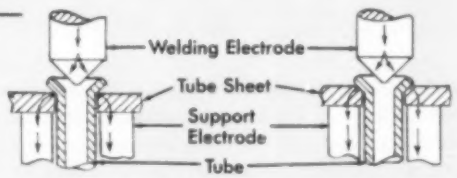


Fig. 3 – Schematic Drawing of Flared Resistance Welded Tube Joints. First approach involved a conical electrode, flared tube and straight tube-sheet hole (left). Final method substituted a prechamfered hole (right)



welding is shown in Fig. 2. The bonds obtained were of the pressure-weld type with a high degree of bonding at the interface of the deformed materials and no melted phase present. The joints produced were strong and leak-free. Welds made without the ring projection on the tube sheet surface were of the nugget type; however, they were nonuniform around the tube and were unsatisfactory. This method – using a flanged tube and tube sheet projection – was not suitable because of the cost.

Final Plan – Subsequently a drilled and reamed tube sheet and a flared tube were constructed. Welding was performed with the conical electrode shown in Fig. 3, left. Preparation was very simple. In the process of welding, initial contact between the components provided a junction having relatively high resistance. Current passing across the point of contact heated the corner of the hole which was then deformed under the forging action of the electrode. Initially, the most satisfactory results were obtained when a low welding pressure was used followed by a higher forging pressure.

The bond produced in a weld of this type is similar to the type associated with a pressure weld. Appreciable plastic flow of softened tube and tube sheet material occurred. The interface oxide films were completely expelled permitting uninhibited recrystallization across the junction. Bonds made in Inconel have strength comparable to that of the parent material and are extremely resistant to thermal shock effects. However, some thinning of the flared portion of the tube wall and displacement of the tube through the tube sheet occurred. Since it is desirable to reduce these effects, the method was modified slightly (Fig. 3, right).

Prechamfered Tube Sheet – The same flared tube was employed, but the edge of the tube-sheet hole was chamfered to eliminate the sharp corner contact between the components. The thickness of the flare section was practically unchanged during welding, and displacement of the tube was reduced to less than one third that in the initial method involving a flared tube.

The deformation characteristics of this weld on a prechamfered joint differed from that of the initial weld on a flared tube without the chamfer since only a small degree of plastic flow of material occurred along the bond interface. The initial surface oxide films were contained along the interface as finely separated particles. The bond obtained tended to be of the recrystal-

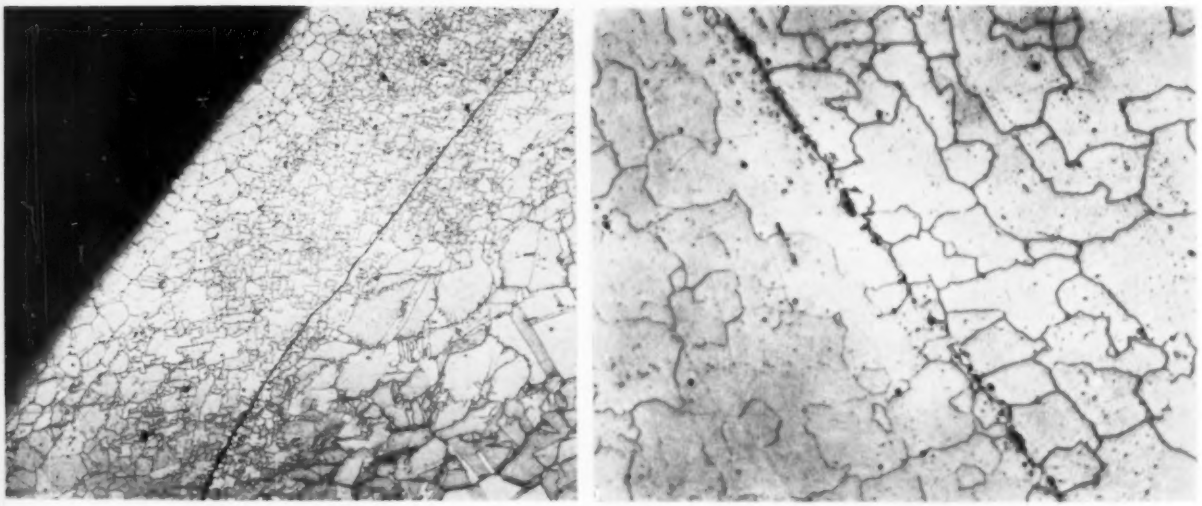


Fig. 4 – Micrographs of Resistance Welded Inconel Joint. Butting surfaces were mated by prechamfering tube-sheet hole. Left, 75 ×; right, 500 ×

lization type. Figure 4, left, shows the excellent joint geometry of the Inconel weld in a prechamfered tube sheet. At low magnification the interface may appear as a line because of a preferential attack which seems to take place during electrolytic or chemical etching. Figure 4, right, shows a bond interface in Inconel containing oxide particles. Grains can be seen extending across the interface.

Evaluation – Metallographic examination determined the type of weld bond obtained, the form of the weld configuration and the length of the bond. The objective was to obtain a weld having sufficient strength, keep wall thinning to a minimum and maintain a bond length of at least 1½ times the tube wall thickness.

Applying hydrostatic pressure to single-tube coupons was effective in some instances for determining relative strength values of welded joints. Pressure applied to the tube side of the tube sheet tended to push out the flared tube from the tube sheet, and gave realistic values of joint strength. Welded clusters were tested to observe the effects of the configuration.

All welded joints were leak tested by helium mass spectrograph techniques to insure freedom from leaks before further testing. Thermal-cycled specimens were leak tested following cycling.

Thermal shock cycling was of value in determining bond strength variations in instances where the intended service temperatures were high. Inconel test configurations, designed to operate near 1500° F., were heated to this temperature and quenched in water cyclically from 15 to 25 times. Specimens were of thin-walled 3/16-in. diameter tubing welded to ⅛-in. tube-sheet coupons. Bond integrity was evaluated in this manner. The test was useful in establishing the limits of variables in the welding schedule.

A thermal stress cycle test was devised for a resistance welded joint in austenitic stainless

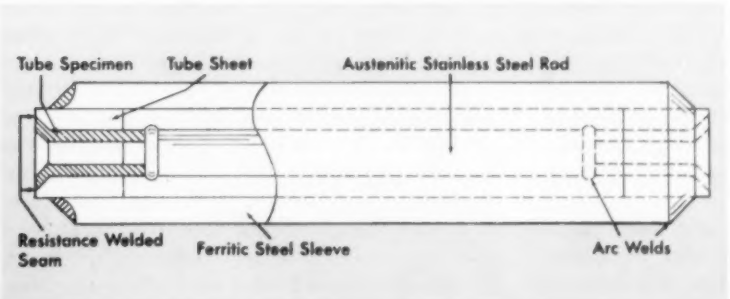


Fig. 5 – Specimen for Thermal Cycle Test

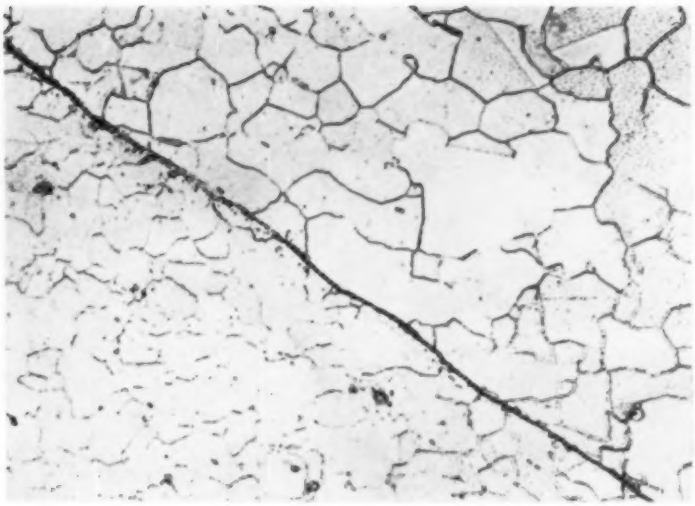


Fig. 6 – Weld Joint in Inconel Made With a Flared Tube but Without Chamfering the Tube Sheet. Constant pressure resulted in heavy oxide film at interface. Variable pressure squeezed out the oxides. 500 ×

steel designed to operate at about 500° F. Here two tube-to-tube-sheet coupons of austenitic stainless steel were welded together, the tubes by a connecting austenitic steel rod and the sheets by a ferritic steel sleeve, as shown in Fig. 5. The shrinkage of the weld metal drew the two tube sheets closer together and provided an initial shear stress for the weld joints. The welded assembly was then heated to 500° F. and cycled between this temperature and room temperature about ten times. During heating, the austenitic material expands about twice as much as the ferritic material, thus adding to the initial stressing. Unsound welds rupture in this test. When complete rupture of the joint did not occur, metallographic examination of the tested joints disclosed the extent of damage to the bond.

Working Schedule – Having established that welding methods involving flared tube and chamfered tube sheet were practical and promising, the next thing was to find the best welding schedules for 3/16-in. Inconel tubing, using ¾-in. to 1-in. square tube-sheet coupons made out of ⅛-in. thick material. A flare angle of 74° was selected, based on the results of a previous investigation. Welding was performed under water to exclude air; the added cooling effect also tends to eliminate overheating.

The first welds, made without chamfering the tube sheet, indicated that a variable pressure schedule produced the most satisfactory welds. Constant-pressure weld schedules resulted in bond interfaces containing large amounts of oxide film, as shown in Fig. 6. A variable-pressure weld schedule caused expulsion of interface material and this produced oxide-free bonds. The deformation characteristics were better than those observed in the constant-pressure welds.

Hydrostatic and thermal shock tests were ineffective; therefore, this type of weld in Inconel was evaluated metallographically. Schedule 1 of the table was selected as being the best, based on bond appearance, bond length (minimum acceptable bond length was taken as 1½ times the tube wall thickness) and the extent of tube wall thinning.

In general, the Inconel welds made in prechamfered tube sheets did not exhibit molten-type bonding. Variations in the quality of the bonds were distinguished by metallographic examination, augmented by thermal shock cycle tests and hydrostatic tests. At relatively high hydrostatic strength levels, specimens that appeared to be of equal quality behaved differently when subjected to a severe thermal shock treatment. The thermal shock cycle test and metallographic examination both were used in the final evaluation. Schedule 2 of the table was ultimately selected for the 3/16-in. diameter Inconel tubing. This schedule produced welds in Inconel that were completely resistant to thermal shock and had bonds of satisfactory length with oxide particles dispersed uniformly.

Foreign Matter – Various surface conditions were investigated to determine their effects on welds made in Inconel. In general, flared tube components which were reasonably clean welded satisfactorily. However, oiled surfaces and slightly oxidized surfaces did not adversely affect

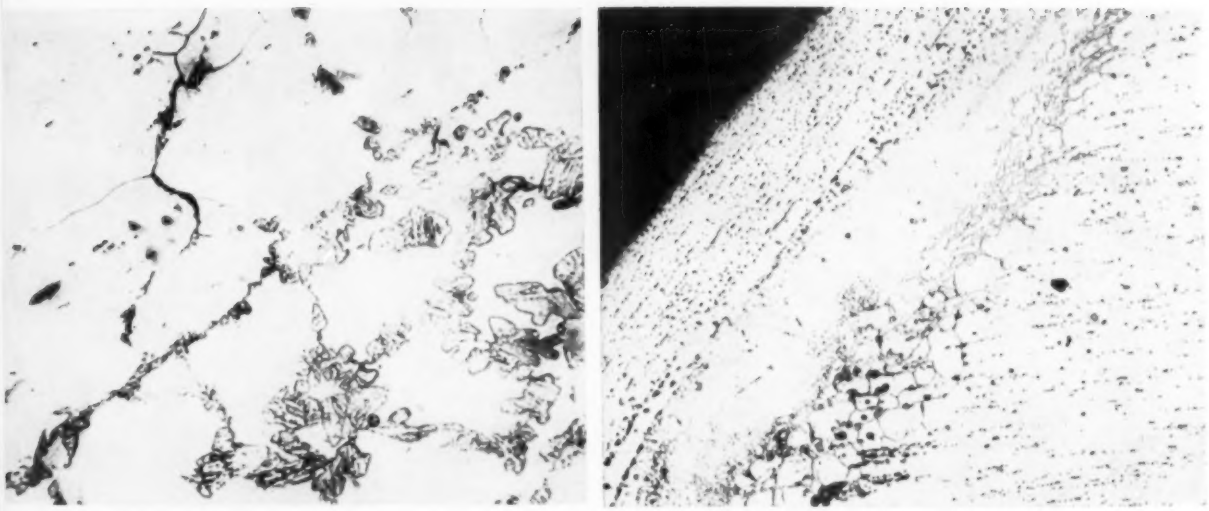


Fig. 7 — Interfaces of Resistance Welded Joints. Type 430 stainless steel (left), 500 ×, and Hastelloy B (right), 75 ×

the welds made without chamfered tube entrances. Similar results were obtained for welds produced in other materials. Welds made with chamfers were more sensitive to foreign matter.

Prechamfered and flared units have been successfully welded in a variety of iron and nickel alloys. In many instances dissimilar metals are easily joined. To date, Inconel, Hastelloy B, Types 316, 347 and 430 stainless steels and tantalum have been joined in tube-to-tube-sheet configuration by resistance welding. The bonds obtained in some of these materials are shown in Fig. 7. The table gives weld schedules devised for some of these materials.

Bonds which are strong and resistant to thermal shock have been produced between Inconel and Type 316 stainless steel, and between nickel and Type 316. The bond between nickel-coated Type 316 stainless steel tubing and a Type 316 stainless steel tube sheet after thermal shock cycling is shown in Fig. 8.

Resistance Welding Schedules

	1	2	3	4	5
Material	Inconel	Inconel	Type 430 stainless	Type 347 stainless	Hastelloy B
Tube O.D., in.	3/16	3/16	3/8	3/8	3/16
Tube wall, in.	0.020	0.020	0.049	0.049	0.020
Tube-sheet preparation	no chamfer	pre-chamfer	pre-chamfer	pre-chamfer	no chamfer
Pressure	variable	constant	variable	constant	variable
Weld force, lb.	500	1650	950	2250	550
Forge force, lb.	1250	—	2250	—	1350
Recompression delay, cycles	5	—	5	—	5
Weld time, cycles	5	6	4	7	5
Weld phase shift, %	56	45	40	65	55
Current decay, cycles	3	3	—	—	3
Current decay phase shift, %	56	41	—	—	55
Impulses	single	3	2	2	single
Cooling cycles	—	6	1	4	—

Welding Tube Clusters— Single-tube coupons were readily welded atop the end of a tubular support electrode. Where multiple tube clusters must be welded, as in a heat exchanger configuration, other support methods had to be devised. Of the various methods evolved, the use of a solid aluminum support electrode, shown in Fig. 9, was the most practical. Here, a sturdy aluminum plate, drilled to the hole pattern of the tube configuration, is assembled on the tubes before flaring. The aluminum support plate is supported by the arms of a fork-type electrode during welding.

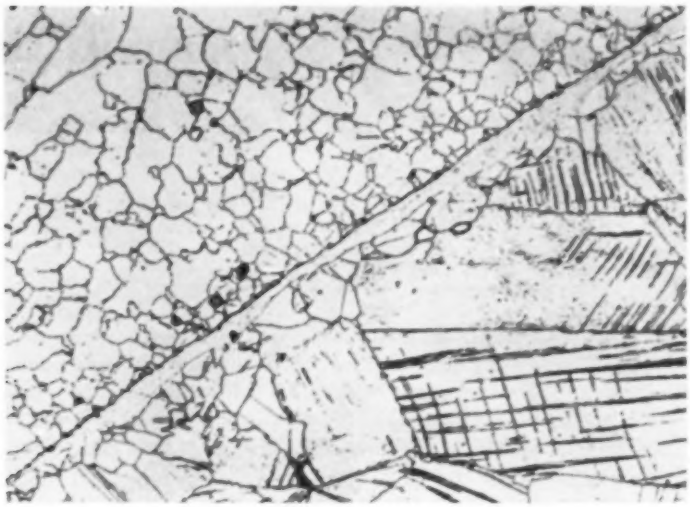


Fig. 8 – Nickel-Coated Type 316 Stainless Steel Bonded to Type 316 Tube Sheet. 500 ×

When bends in the tubes are encountered, two such electrode plates are required. The plate provides good current distribution and minimizes distortion of the tube sheet. After welding, the electrode plates are removed by dissolving in a caustic soda solution.

Test clusters were also welded successfully on support plates made of Cerrobend (a low-melting alloy) and copper. When Cerrobend was used, the support plate was either plated with or encased in a thin sheet of copper. The copper provided a good conducting surface to prevent possible overheating or arcing between the Cerrobend and the tube-sheet material.

Thick tube sheets have been welded using only a peripheral contact technique. Either single or multiple contact or full circumferential contact is used, and the type used depends on the particular conditions.

The techniques developed and used in fabricating relatively small clusters can also be used to weld large numbers. Large-diameter thin tube sheets introduce a problem. Deflection of the sheet may be considerable if edge support techniques are used, and the use of dissolvable aluminum support blocks may be undesirable. A more practical approach to this problem would be to use clamp-on electrodes.

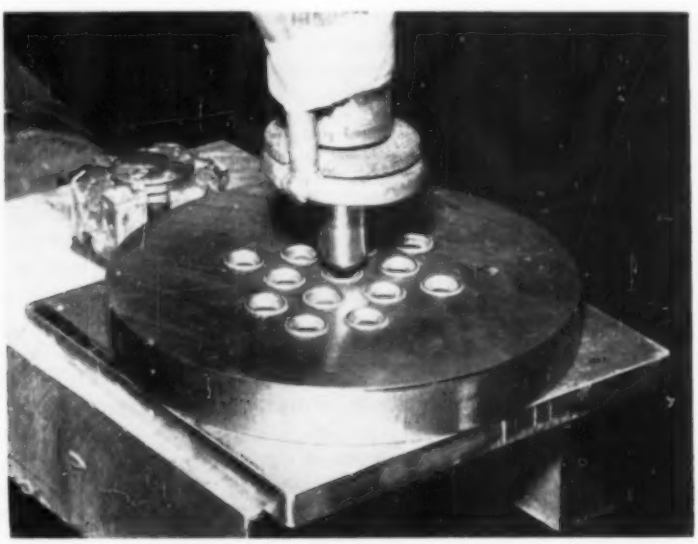


Fig. 9 – Simulated Tube Bundle Being Welded. Square aluminum support plate is itself supported by arms of fork-type electrode

How to Avoid Hydrogen Pickup in Descaling Titanium Alloys

*By Q. D. WHEATLEY**

Immersion time in the titania-modified hydride bath should be as short as possible. Optimum conditions for descaling the hydrogen-sensitive 5Al-2.5Sn titanium alloy are obtained with a molten caustic bath containing 0.4 to 0.6% NaH, 0.35% TiO_2, and 10 to 20% Na_2CO_3. Treatment time should be 30 to 60 sec. at 610 to 645° F. (L12n; Ti-b)

EMBRITTLEMENT of titanium by hydrogen has been a major problem for producers and fabricators. While hydrogen contamination can occur in many stages of processing, fused salt baths used for descaling the metal can be a trouble spot.

In earlier work, reported in *Metal Progress* for February 1956, we investigated descaling commercial-purity titanium in conventional sodium hydride baths. It was found that significant hydriding of this grade of titanium occurs if the metal is treated longer than required to remove the scale. Another significant point reported in the 1956 article was that commercial-purity titanium could be descaled efficiently in a modified hydride bath prepared by saturating the caustic melt with titanium dioxide (about 0.35%). The modified bath gave a marked decrease in hydrogen pickup and lower metal loss compared with a conventional hydride descaling bath. Descaling was rapid and surface finish was good.

With conventional hydride baths, treatment time, temperature and hydride concentration are important variables in regulating hydrogen contamination. However, when commercial-purity titanium is descaled in the modified bath, these variables need not be so closely controlled as is required for the titanium alloys. This paper will report our recent findings on optimum conditions for use of the titania-modified hydride bath for descaling titanium alloys.

Experimental procedures were essentially the same as for the study of commercial-purity titanium. Different alloys were obtained in sheet form from several commercial sources. Test pieces were treated in a hydride bath that had been saturated with titanium dioxide. Samples were water quenched and then given a brightening pickle in mixed nitric-hydrofluoric acids (see Table I). Hydrogen analyses were made by the equilibrium-pressure method. Blanks to establish original hydrogen content were taken from areas immediately adjacent to test pieces.

Preliminary experiments showed that titanium dioxide did not have as strong an effect in suppressing hydrogen contamination of titanium alloys as it did with commercial-purity titanium. These experiments also showed that the different alloys vary markedly in their susceptibility to hydrogen pickup. For example, with a treatment time of 5 min., the various alloys showed a hydrogen pickup as follows: 5Al-2.5Sn, 241 ppm.; 6Al-4V, 124; 4Al-4Mn, 27; 2Fe-2Cr-2Mo, 25; 8Mn, 4; 3Al-5Cr, 2. These ratios of sensitivity to hydrogen pickup are only approximate. However, the Al-Sn alloy appears to be the most sensitive. Since it is desirable to descale all titanium materials in a single bath, we felt it was important to establish optimum conditions for the most sensitive alloy.

*Research Div., Electrochemicals Dept., E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

The Al-Sn stock used in further tests was thin sheet (0.018 in.) that had a light scale, such as is formed during annealing. The sheet was chosen to magnify the effect of descaling on hydrogen pickup, because, generally, hydrogen pickup is an inverse function of sample thickness.

Previous studies with commercial-purity titanium, and the preliminary experiments with titanium alloys, had shown that long immersion time, high temperature and high hydride concentration will result in high hydrogen pickup. Of these variables, it was felt that immersion time was probably the most important. Experiments were performed in which immersion time ranged from one-half to several minutes, hydride concentrations ranged from 0.4 to 1.6% and temperatures ranged from 604 to 903° F. Tests using any combination of high temperature, high hydride and long immersion invariably led to high hydrogen pickup. Exposure of subsequent samples to the bath was, therefore, kept to the minimum required for effective scale removal. The results of experiments, performed under near optimum conditions, are given in Table I.

Table I – Hydrogen Absorption by Aluminum-Tin Titanium Alloy in Modified Hydride Baths*

Immersion Time	Bath Temperature	NaH	Na_2CO_3	Pickle† Time	Hydrogen Pickup
1 min.	669° F.	1.6%	10%	1 min.	52 ppm.
½	604	0.5	10	2	7
1	640	0.6	10	2	9
1	626	1.2	0	2	26
1	608	0.5	10	3	17
1	608	0.5	10	3	12 } Ave. =
1	608	0.5	10	3	10 } 12
1	608	0.5	10	3	9

*Bath saturated with TiO_2 (about 0.35%).

†Pickling solution consists of 20 vol. conc. HNO_3, plus 2 vol. conc. HF, 78 vol. H_2O; temperature 77° F.

The data show that the Al-Sn alloy can be descaled satisfactorily and hydrogen pickup held to a low value by using a treatment time of 1 min. or less, low bath temperature and low hydride concentration. Hydrogen pickup can be limited to the range of 12±5 ppm., under these optimum conditions.

Optimum Descaling

For best results with thinly scaled material, the molten caustic bath should contain 0.4 to 0.6% NaH, 0.35% TiO_2 and 10 to 20% Na_2CO_3. Treatment time should be 30 to 60 sec. at 610 to 645° F. Sodium carbonate maintains fluidity of the bath and prevents excessive dragout. Results cited above were obtained with the most sensitive alloy, and on thin material. Thicker sheet should show even smaller amounts of hydrogen pickup when treated under optimum conditions.

However, it should be noted that much of the sheet descaled during normal mill operations bears a relatively thick, and often nonuniform, scale rather than the thin scale that forms on annealed material. Thickly scaled sheet will, of course, require longer descaling cycles. Nonuniform scale may also result in nonuniform hydrogen pickup. The important point to remember is that descaling cycles should be kept to the minimum time limit required for effective scale removal.

Pickling Tests

The effect of drastic acid pickling on hydrogen contamination was also looked at. Two samples of Al-Sn alloy were descaled in the modified hydrogen bath and given the usual acid dip. Portions of the treated samples were reserved for hydrogen analyses. The remaining portions were pickled in mixed nitric-hydrofluoric acids until the total gage loss was 0.004 in. (samples were originally 0.018 in. thick). The blanks, descaled pieces and drastically pickled pieces were then analyzed for hydrogen. The test pieces given a descaling and simple acid dip treatment absorbed 46 and 31 ppm. hydrogen, respectively. The corresponding samples given the drastic acid pickle showed, respectively, only 32 and 7 ppm. hydrogen pickup. Although there is some variation in the duplicate analyses, it is clear that a drastic acid pickle will remove significant amounts of hydrogen absorbed during descaling. The data are not extensive enough to fix the percentage improvement accurately, but it appears that at least 30% of the absorbed hydrogen can be removed by such a treatment.

It is unlikely that all types of stainless and alloy steels can be descaled efficiently under the mild conditions required for treating the Al-Sn alloy. Since the other titanium alloys are much less sensitive, most of them can probably be descaled without undue hydrogen contamination by using descaling conditions which are milder than usual, but still adequate for alloy steels.

An English Turbogenerator Explodes

*By TOM BISHOP**

The turbogenerator accident at Calder Hall atomic power station was not due to internal defects in forged components (as have plagued American power stations recently) but to overspeeding caused by nonfunctioning automatic safety valves. (A7p, W11k, W11p)

WHEN A HIGHLY STRESSED turbogenerator fails explosively, it is perhaps natural for metallurgical detectives to think immediately in terms of recent similar disasters due to hairline cracks in alloy steel forgings and to question anew the efficiency of ultrasonic testing of large components. They would be on the wrong track in appraising turbine No. 5 which broke up on June 28, 1958, at the English atomic power station at Calder Hall. The machine which failed was the fifth 23,000-kw. unit to be installed; acceptance tests were being carried out, but the U. K. Atomic Energy Authority had not formally accepted delivery.

At about 7:40 p.m. on that date, the foreman in charge of reactor No. 3, which was providing steam for No. 5 turbogenerator, noted indications on his reactor instruments which suggested that it might be desirable to shut down the reactor. At about 7:59 p.m. he warned the electrical control room that this might be necessary. At about 8:03 p.m., in accordance with his standing instructions, he pressed the shutdown button. As the last control rod went home, the foreman

*John Miles & Partners (London) Ltd.; Consulting Editor, *Metal Progress*.

General View of Generator at Calder Hall Atomic Energy Plant, England, Wrecked by Overspeeding

heard an explosion – the turbogenerator had disintegrated.

The operator in the turbine room first suspected that conditions were other than normal when he sensed that the speed of the machine was increasing. He attempted to stop the machine by manual control, but it became clear that it was overspeeding and beyond control. The machine vibrated violently; flames came from the generator and it finally broke up. As shown in the view on the opposite page, major rotating parts remained within the housings, but large pieces of shaft and other parts were ejected and caused other damage. Fortunately there were no casualties.

The Cause

The power plant foreman, who was the first man on the scene after the accident, found the governor valve and the runaway stop valve on the lines serving the high-pressure stage of the turbine partly open; this was confirmed by other witnesses. The valves on the low-pressure lines had operated satisfactorily. With the valves in such a position, there would have been an ample supply of steam to the turbine to cause it (in the absence of any electrical load) to overspeed to destruction.

The runaway stop valve was tapped with a hammer during dismantling, but did not move; the governor valve was jacked open a distance of 0.58 in. and then jammed completely. When the two valves were dismantled, it was found that the spindle of the runaway stop valve had jammed in the bushing, and the tail of the governor valve had jammed in its guide. From this evidence, the investigating committee was satisfied that the simultaneous failure of these two valves to close automatically had caused the turbogenerator to overspeed and ultimately to disintegrate.

Examination of the Valves

The spindle of the runaway stop valve was found to be marked in three different ways: (*a*) by light longitudinal scratches, (*b*) by heavy longitudinal scoring, and (*c*) by an interlacing of scores in a general longitudinal direction but with a random circumferential movement (called "filigree").

The tail of the governor valve showed similar marks but the filigree marking was most pronounced (Fig. 1). In addition to these marks, the tail of the governor valves showed clearly

(Continued on p. 146)

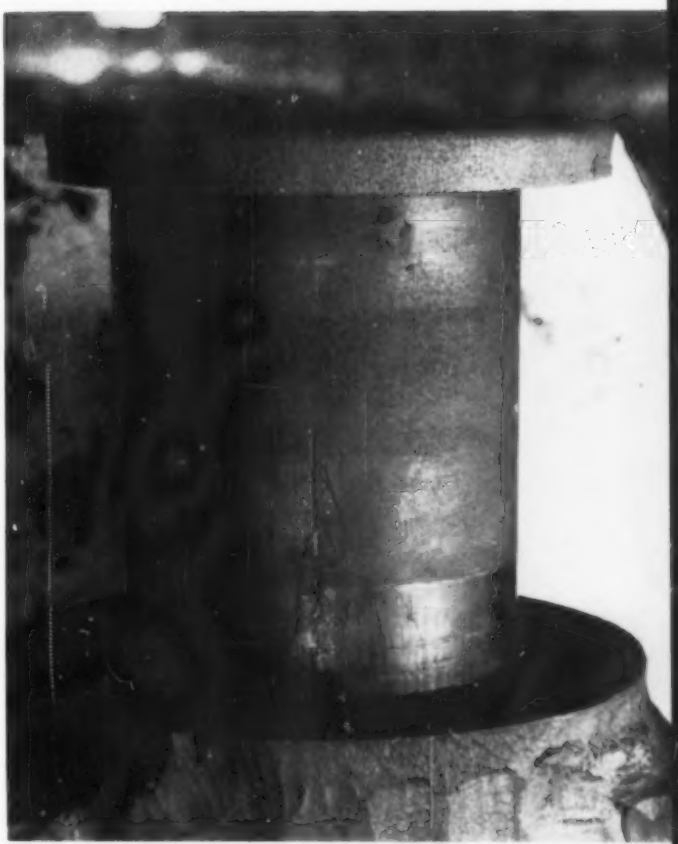
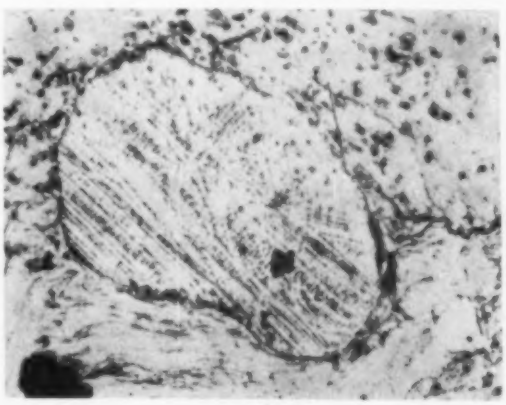


Fig. 1 – Tail of the Governor Valve. Note scoring generally in longitudinal direction. Also three broad circumferential bands roughened as by shot-blasting. Lowest band has its finished surface almost undamaged

Fig. 2 – Particle of White Cast Iron Shot (Note Dendritic Structure) Embedded in Governor Valve Guide. X 100



Book Review

A Two-Volume Introduction to Physical and Process Metallurgy

BASIC METALLURGY, Vol. I, A. W. Grosvenor, Ed., American Society for Metals, Cleveland, 2nd printing, October 1958. 676 p. $12.50

*Reviewed by JOHN A. SHANDLEY**

RECOGNIZING THE NEED for an up-to-date textbook in a two-year adult education program in metallurgy, 58 authors – largely members of the Philadelphia Chapter, with A. W. Grosvenor as editor – have produced "Basic Metallurgy", an excellent book for their purposes. Temple University provides the facilities, and the chapter's Educational Committee participates in the management of the course. This new textbook is now being used at the General Motors Institute to teach mechanical and industrial engineering students the rudiments of metallurgical engineering.

The book's continuity of style and logical development of ideas from one chapter to the next is remarkable when one considers the multiplicity of authors. "Basic Metallurgy" is effectively indexed and uses an abundance of illustrations and charts. Since it is, essentially, an elementary textbook, its usefulness as a reference work is limited.

The text reviews briefly chemical reactions, the structure of the atom, the kinetic theory of temperature and many other basic tools of the metallurgist. This refresher section is more than ample for a student having a high school chemistry and physics background. There is a rather extensive treatment of the unit processes used to produce various metals, with emphasis on iron and steel production. The authors have generally pointed out the cause and effect relationships that exist between processing and ultimate properties. The treatment of nonferrous and ferrous alloys is unusually complete. Two topics, "The Effect of High and Low Temperatures on Metals" and "The Ingot" (in steelmaking), each warrant a chapter. In most texts these topics are not singled out as they are here. Many recent concepts are explained so adeptly that they will be a source of satisfaction to both the student and the practicing engineer (who may wish to bring himself up-to-date). Dislocation theory is used to explain plasticity and strength and the work of Huinier and Preston is used to describe age hardening. However, the application of the more recent work on tempering of hardened steels should be treated in greater detail in a revised edition.

An unusual feature of Basic Metallurgy is the division of each topic into two chapters. The "A" chapters consist of elementary treatments of the material while the "B" chapters are suitable for a more advanced course. This is the formula used at Temple University, in Philadelphia. In most instances, it would seem necessary to repeat the "A" chapter before studying the corresponding "B" chapter. This may lead to greater retention of facts, even though the burden seems to be placed largely on the second course.

*Head, Metallurgy Section, General Motors Institute, Flint, Mich.

BASIC METALLURGY, Vol. II, G. William Zuspan, Ed., American Society for Metals, Cleveland, 1957. 232 p. $7.50

*Reviewed by WALTER J. KINDERMAN**

"Basic Metallurgy, Vol. II" covers metallurgical equipment and laboratory techniques and is a fitting complement to the general study of metals covered in "Basic Metallurgy, Vol. I".

Although this book was written by the mem-

*Yarnall-Waring Co., Chestnut Hill, Philadelphia, Pa.

bers of the Philadelphia Chapter for the use of students in the A.S.M. sponsored Evening Metallurgy Course at Temple University, it should also satisfy a laboratory training need at other institutions. When its contents are better known, it is bound to win a place as a handy reference volume in the laboratory. Its 232 pages contain a surprising wealth of practical information, clearly indexed for rapid and easy accessibility.

The introductory chapter gives the reader a fine perspective of the range and value of empirical test data and how it can be most effectively used. Tensile and hardness tests each merit a chapter. Other mechanical tests, impact, fatigue, creep, compression, bending, cupping, offset and torsion tests, are viewed from the standpoint of equipment, test specimens, procedure and interpretation of results. The chapter on nondestructive tests defines and explains visual, magnetic, radiographic, magnetic particle, ultrasonic and spectrographic equipment and procedures.

One of the highlights of the text is a chapter on microscopic investigation. The reader is introduced to the principles of optics, but is spared the complex details of objectives and illumination systems. The preparation of specimens for microscopic examination is described thoroughly. Even the basic principles of the electron microscope are included.

The longest chapter discusses pyrometry, stressing on-the-job trouble shooting and practical operations.

The text concludes with short chapters on corrosion testing and miscellaneous testing.

The appendix contains 17 useful data sheets designed for the budding metallographer.

Short Runs

Titanium Alloy for 1100° F.

A NEW TITANIUM ALLOY, MST 881, has elevated-temperature properties which surpass those of other titanium alloys as shown by curves in Fig. 1. Developed by Mallory-Sharon Metals Corp., Niles, Ohio, after three years of research, the designation of the alloy comes from the percentage of alloying elements which it contains: 8% Al, 8% Zr and 1% Ta and Cb combined. Above 800° F., the alloy extends the useful range of titanium by 200 to 300° F. and it provides an

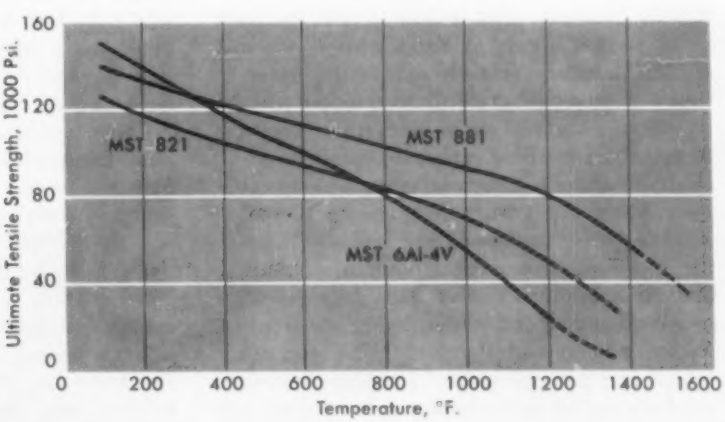


Fig. 1—Comparison of Strength Properties of High-Temperature Titanium Alloys

additional 30,000 psi. tensile strength. This new alloy has useful short time strength up to temperatures of 1500° F.

Where it Can Be Used

MST 881 provides design engineers with two new areas of high-temperature strength: For applications which require stability over long periods, it offers additional useful strength in the range 600 to 1100° F. For construction of rockets and missiles, where short-time strength is important, the alloy offers additional strength at all temperatures from 400 to 1500° F.

In rapidly rotating parts, where stress is proportional to density, and in aircraft and missile structures where weight is a prime consideration, the strength-to-density ratio of metals is an important criterion of selection. This value for MST 881 is compared with three steels at various temperatures in Fig. 2, based on data supplied by Mallory-Sharon. On this basis, the short-time strength of MST 881 is superior to 304 stainless, PH 15-7 Mo, and A-286 at all temperatures above 600° F.

MST 881 is commercially available as bars, billets and forging stock. Techniques for production of sheet materials are under study. Lee S. Busch, Mallory-Sharon's technical director, states that 881 alloy opens up new possibilities for use of titanium in Mach 3 jet engines to a depth of seven or eight stages and in airframes and substructures for high-speed aircraft and guided missiles.

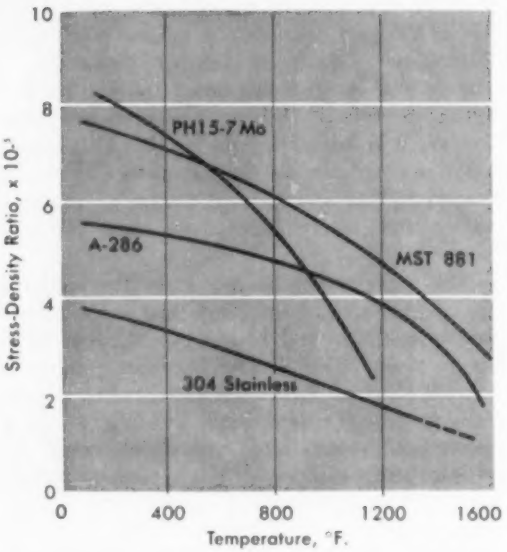


Fig. 2 – How MST 881 Compares With Other Metals on a Strength-to-Density Basis at Elevated Temperatures. (Stress-density ratio is ultimate strength in psi. to density in lb. per cu.in.)

Something New in Testing Machines

RECENTLY, Tatnall Measuring Systems Co., a subsidiary of Budd Co., unveiled a 400,000-lb. universal testing machine incorporating several novel features. Adjustable grips, exerting 10,000-psi. hydraulic pressure, clamp onto specimen ends, making it easy to install tests in the machine. Auxiliary controls enable the tester to follow a preset program to completion without attention. Various other innovations combine to make the machine extremely versatile.

The machine is comparatively simple to operate. Since the lower grips are in the table (rather than in the crosshead), it is easy to place the specimen in a vertical position. Manually operated calibrated screws align grips precisely to avoid bending and torsion forces which might reduce accuracy of the test. The grip teeth (small and pyramid-shaped for firm clamping) are fully seated by hydraulic action before any force is applied to the specimen.

Incorporating an electronic weighing system, the machine reads into a 30-in. diameter multirange dial indicator. Load signals can be fed into a flat-bed X-Y recorder, a digital indicator, automatic typewriter, printer or card puncher; they can also be employed in closed loop feedback circuits for automatic control.

Cyclic loading is possible – an unusual feature. Since the specimen does not have to be removed from the grips if it is to be tested in both tension and compression, the load can swing back and forth between two extremes. In a sense, this can be regarded as a fatigue test. Cycles may vary from 30 per sec. to one per day. The machine is versatile enough so that cyclic loading can be entirely in tension or compression. The tester has been purchased by the Alabama Polytechnic Institute, Auburn, Ala.

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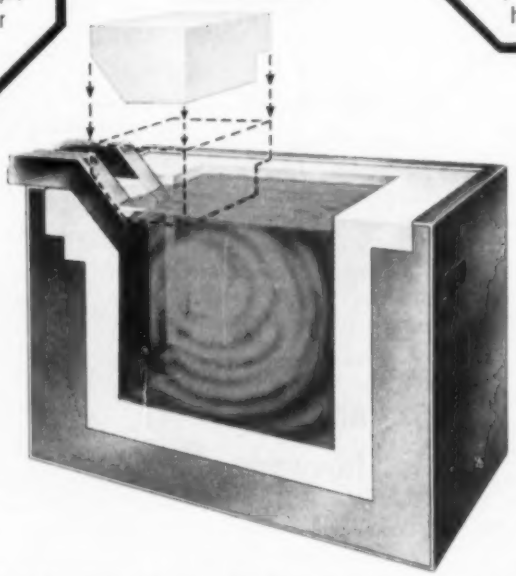

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Correspondence

Minimizing Distortion

FAIRFIELD, N.S.W., AUSTRALIA

During my visit to the United States for the Second World Metallurgical Congress, it became very evident that gear metallurgists both there and in other countries are very conscious of the need for more detailed investigations of the effects of *surface* carbon content on the service of carburized gears. In raising the matter during the panel discussion on "Minimizing Distortion," I stated that, although we in Australia have had little opportunity to study the matter, our experience suggested that surface carbon is a rather more important factor in dimensional consistency than is case depth.

On p. 128 of the A.S.M. publication, Story of Second World Metallurgical Congress, the above statement was unfortunately misreported with the words "surface condition, as well as case depth, is more important than carbon content of the case."

I raise this merely as a matter of accurate reporting of my remarks. I fully realize that other metallurgists in this field may well consider the statement as reported to be more technically correct than my own view as expressed in the first paragraph of this communication.

I hope that no one will consider this minor error to be in any way a criticism of the wonderful benefit we all derived from this outstanding event in our lives. The smooth, efficient running of the Congress and the rapidity with which the book was published are indeed of the highest order.

F. P. HEARD
Chief Metallurgist
Borg-Warner (Australia) Ltd.

The Editors regret that Ipsen Industries, Inc., Rockford, Ill., was inadvertently omitted from the list of companies which supplied information for the special staff report, "Potential for Higher Temperature Carburizing", in the October issue of *Metal Progress*.

Adam the First Ironworker (?)

Some doubts may be cast upon the authoritative statement (Genesis 4:22) that Tubal-cain was the "instructor of every artificer in brass and iron". At least the maker of the Byzantine ivory illustrated below seemed to have a different idea. This plaque from a casket dating from the 11th or 12th century shows Adam and Eve at the forge. Seemingly, Adam passed down his skill to the seventh generation, who got the credit in Holy Writ.

Byzantine Ivory Showing Adam and Eve at the Forge. (Courtesy Metropolitan Museum of Art, New York City)

Etchant for Cerium and Cerium Alloys

DENVER, COLO.

A search of the literature for a suitable etchant for cerium or cerium-base alloys shows very little data published on the subject. The information available is limited to discussions of air etching techniques or etching problems due to the reactiveness of the cerium. Our metallography department therefore accepted the job of finding an etchant for cerium and cerium-base alloys. A very successful combination of etchants was consequently developed which not only satisfactorily revealed the structure but also rendered the specimen surface somewhat passive to subsequent air oxidation.

(*Continued on p. 122*)

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Etchant . . .

A mixture of 6 ml. HNO_3 and 5 ml. glycerine, swabbed on the specimen, effectively stains the metal grains. Weaker concentrations of HNO_3 overetch boundaries while stronger concentrations tend to pit the matrix. A specimen of commercially pure cerium etched in this manner is shown in Fig. 1. The stain may be removed by a second swabbing with a mixture of 42 ml. H_3PO_4, 11 ml. two-ethoxyethanol and 47 ml. glycerine. Fig. 2 shows the same specimen after the removal of the stain.

DONALD T. KLODT
ROBERT J. MCMANIS
Metallurgy Div.
Denver Research Institute
University of Denver

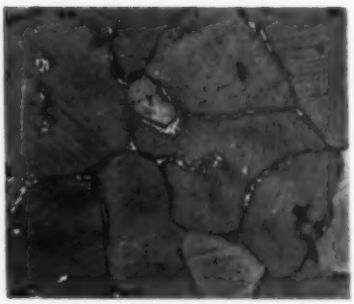

Fig. 1 – Commercially Pure Cerium Etched With 6 Ml. HNO_3 and 5 Ml. Glycerine. 125 ×

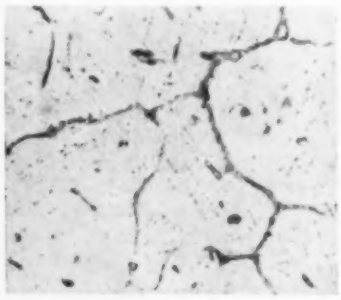

Fig. 2 – Same Specimen Swabbed With Mixture of H_3PO_4, Two-Ethoxyethanol and Glycerine. 125 ×

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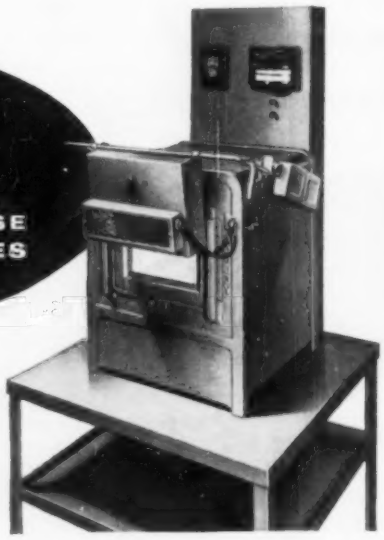
(bench type)



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Write for new catalog of electric furnaces and ovens.

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MH-4	10	6	18	23	25	29	4500	1850
VH-3	8	6	14	21	25	25	3600	1850
VH-4	10	6	18	23	25	29	4500	1850
VH-4B	10	8	18	23	27	29	4800	1850
VK-6	8	6	14	25	28	25	4650	2000
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Titanium In Cast Iron

HIGH BRIDGE, N.J.

In the article "Titanium in Nodular Cast Iron", by A. Tominaga, I. Aoki and T. Tottori, in the August issue of *Metal Progress*, an error in translation appears to have been made. The authors state that titanium is well known for its adverse effects, but go on to say "titanium by itself is no obstacle to formation of graphite nodules". This is obviously a contradiction.

Additions of titanium of approximately 0.10% have been found to destroy formation of nodules. The destruction of nodulization may well be additive, but amounts described here are nearly sufficient to attain this without additions of arsenic, tin, or bismuth.

P. E. HEGMEGEE, JR.
Plant Metallurgist
Taylor-Wharton Iron and Steel Co.

EDITOR'S NOTE: The correspondent's remarks are correct; however, the original contribution offered data to support the contention that titanium up to 0.10% did not affect nodule formation.

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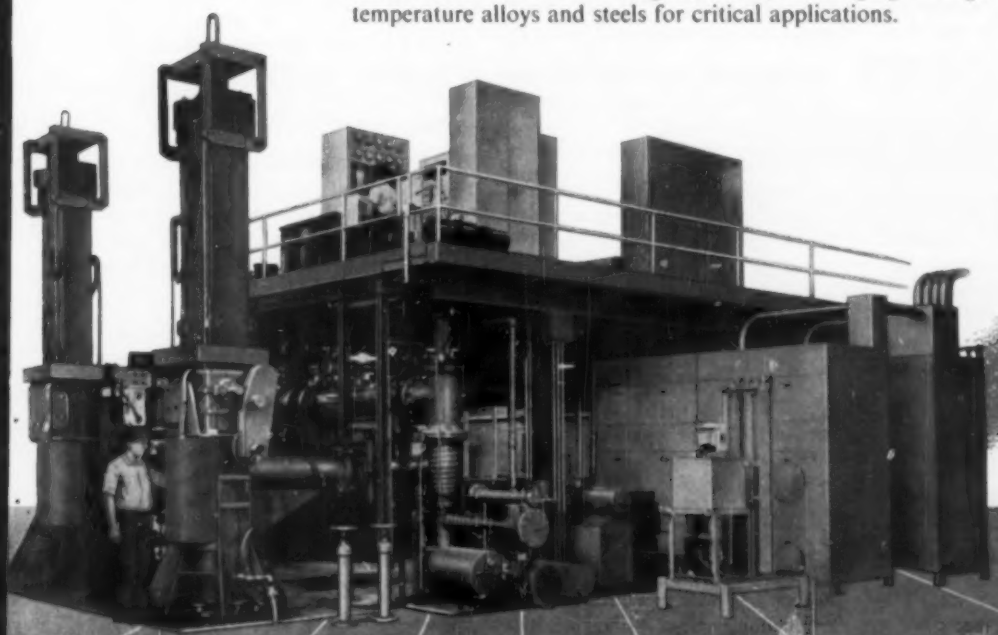

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Personal Mention

Arthur L. Shields

ARTHUR L. SHIELDS has retired from Westinghouse Electric Corp. in Springfield, Mass., after 35 years to act as a consultant. Mr. Shields entire career with Westinghouse was spent in materials engineering, first in the company's research laboratories, and later in the transformer division in Sharon, Pa. He was then transferred to the appliance department at Springfield, where he was manager of materials and process engineering, directing the selection and fabrication of ferrous, nonferrous and nonmetallic materials for use in motors and appliances.

He graduated from Westminster College in New Wilmington, Pa., with a bachelor of science degree in chemistry, and in 1917 enlisted in the U. S. Army, serving in France as an officer in the field artillery. After his discharge, he first joined Westinghouse, but two years later left to teach science in the Niles (Ohio) High School, returning to Westinghouse permanently in 1923.

A 30-year member, he is a past chairman of the Springfield Chapter and has been active on that Chapter's executive committee and education program. He was also a member of the American Society for Testing Materials for many years and served on the executive committee of the New England District.

Richard Cornew is currently casting sales specialist for Aluminum Co. of America, Los Angeles.

Harold G. Huckelberry is now resident field engineer in Davenport, Iowa, for Leeds & Northrup Co., handling their sales in eastern Iowa and northwestern Illinois. Formerly this area was served from the Chicago district office.

Roland M. Brown is on a two-year leave of absence from the bar, plate and forged products division of the U. S. Steel research and development department in Monroeville, Pa., serving in the U. S. Army. He is currently stationed with the 11th Ordnance Co. (DAS) at Ft. Devens, Mass.

Harris A. Clotworthy, who retired from IBM late in 1955, is now representative for the steel warehouse of Edgcomb Steel of New England, Inc., Milford, Conn., and Industrial Hardware Mfg. Co., Inc., New York.

Pierre P. Turillon is currently working at Utica Metals Div. of Kelsey-Hayes Co., Utica, N. Y., where he is a research metallurgist.

Thomas B. Rance has been transferred to the Beauharnois, Que., Works, Aluminum Co. of Canada, as potroom control supervisor.

Alvin J. Jacobs, who recently received his doctorate in metallurgical engineering from Ohio State University, is now engaged in postdoctoral work with Prof. G. W. Rathenau at the University of Amsterdam in Holland.

Athan Stosuy, formerly manager of sintered metals laboratory for the International Business Machines Corp., Poughkeepsie, N. Y., is now technical director, American Powdered Metals, North Haven, Conn.

Gunvant N. Maniar, a recent graduate from Stevens Institute of Technology with a master's degree in metallurgy, is attending the University of Michigan to continue his studies in metallurgical engineering.

Daniel J. Murphy, formerly at Los Alamos Scientific Laboratory, Los Alamos, N. M., is now professor of metallurgy at the University of Arizona in Tucson.

Fred K. Whiteside has been named sales representative in the Hartford, Conn., sales district of Selas Corp. of America, Dresher, Pa.

Ben A. Wilcox, after receiving his master's of science degree in metallurgical engineering from Stanford University, reported to Wright-Patterson Air Force Base, Ohio, as a Second Lieutenant in the Air Force, assigned to the Wright Air Development Center. Upon completion of his three-year tour of duty, he will return to Stanford to continue his studies toward a doctorate in metallurgical engineering.

A. C. Francisco has joined Boeing Airplane Co., Seattle, Wash., division, as a ceramic research engineer in the materials and process systems group.

J. R. Stitt, research and welding engineer for the R. C. Mahon Co., Detroit, was the recipient of the 1958 George N. Sieger Memorial Award from the Detroit section of the American Welding Society. Stitt was honored for making the most outstanding individual contribution to the growth of the society in the past ten years. Prior to joining Mahon, he was an associate professor at Ohio State University where he organized the first complete curriculum in welding engineering leading to a degree.

F. D. Brookshire, formerly a metallurgical engineer at General Motors production engineering section, Detroit, is now a metallurgist at GMC Truck & Coach Div., Pontiac, Mich.

Richard O. Berg has retired as plant manager of Michigan Steel Tube Products Co., Detroit, after 41 years in that capacity.

William Nukulas, formerly chief engineer of Kelvinator Div. of American Motors, is now chief engineer of South Bend, Ind., Div. of Curtiss-Wright Corp.

William B. Stoddard, Jr. is now assistant manager of electrochemical research for Hanson-Van Winkle-Munning Co., Matawan, N. J.

T. C. Sherman, after 42 years of service, has retired as Washington representative and district manager of the Washington, D. C., office of Allegheny Ludlum Steel Corp.

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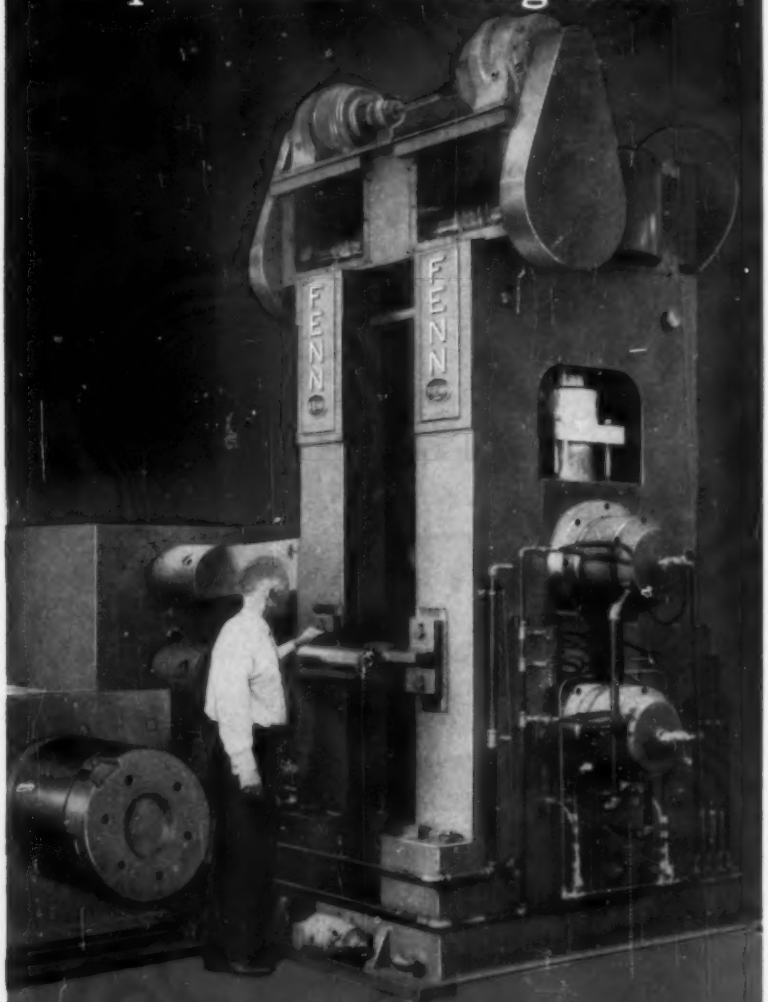

The inherent design of Fenn Rolling Mills achieves greater flexibility . . . extremely high separating forces . . . with dependability that only building to the highest quality standards can provide. Typical is the large heavy duty Fenn Precision Rolling Mill illustrated above. A combination Two-High/Four-High mill, with 16½" diameter rolls, it offers extreme versatility in rolling new alloys with high tensile strengths and is adaptable to either hot or cold rolling.

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Personals . . .

Albert Bennett has been assigned to the technical staff of the Minuteman Project with Aerojet-General Corp., Sacramento, Calif., as a specialist on materials.

R. H. Emannelson recently joined the metallurgy section of Babcock & Wilcox Research Center, Alliance, Ohio. He was formerly with the Westinghouse Electric Corp. in Blairsville, Pa.

James E. Koss is now working for the Beryllium Corp. at their nuclear division in Hazelton, Pa., as production supervisor. He was formerly employed by Sylvania Electric Products, Inc.

David H. Gurinsky, on a year's leave of absence from Brookhaven National Laboratory, Upton, L. I., N. Y., is working with the metallurgy division of General Atomic for the next year and will be located at their Torre Pines Laboratory in San Diego, Calif.

Joseph J. Warga has been promoted to assistant senior engineer, applied studies department of the Polaris development project at Aerojet-General Corp., Sacramento, Calif.

H. R. Grant was recently appointed head of the development engineering department of the solid rocket plant of Aerojet-General Corp. in Sacramento, Calif.

Robert F. Harvey is currently working in the research and development division of the solid rocket plant of Aerojet-General Corp., Sacramento, Calif., as a project engineer on the Navy Tartar missile project, developing the Tartar dual thrust rocket motor. In the same plant, **Michael I. Bricksin** is a specifications engineer-metallurgist, engineering specifications section.

F. S. Gardner has left his job as supervisor of metallurgical research at the General Electric Co. power transformer laboratory to become project manager of Nuclear Metals, Inc., Cambridge, Mass.

Eugene B. James is currently foundry metallurgist and engineer for Clark Bros. Co., a division of Dresser Industries, Inc., Olean, N. Y.

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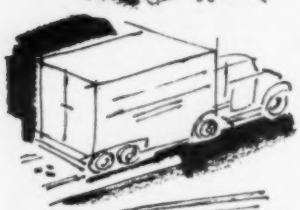

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OFFICES IN PRINCIPAL INDUSTRIAL CITIES

Personals . . .

J. Bruce Wagner, Jr. recently joined the faculty of the department of metallurgy at Yale University as an assistant professor. For the past two years, he was on the staff of the metallurgy department of Pennsylvania State University.

John J. Figliozzi is now assistant metallurgist of the welding and heat treating section of Combustion Engineering, Inc., East Chicago, Ind.

John T. McCormack has left Reynolds Metals Co. to return to teaching. He has joined the industrial engineering faculty at Clemson (S. C.) College where he will teach metallurgy while developing a department of metallurgical engineering. At the same time, he will be engaged in consulting work.

J. W. Semmel, Jr., formerly assigned to the General Electric Co. research laboratory, has been transferred to the G. E. Flight Propulsion Laboratory in Evendale, Ohio, as a consulting metallurgist in materials development.

Willard Roth has joined Lindberg Industrial Corp., Chicago, as manager of engineering. He was formerly with the Westinghouse Electric Corp. industrial heating division as manager of custom furnace section, commercial engineering department.

A. John Birkle, a June graduate of the University of Wisconsin with a master's of science degree in metallurgical engineering, has accepted a position with the U. S. Steel Corp. applied research laboratory in Monroeville, Pa., as an assistant technologist. He is currently assigned to Atomics International and will work on nuclear reactor material problems on a one-year contract basis with U. S. Steel.

Michael Kestigan has accepted a position as member of the technical staff at the David Sarnoff Research Center of Radio Corp. of America Laboratories at Princeton, N. J. He was formerly associated with the pigments department of E. I. du Pont de Nemours & Co., Inc., in Wilmington, Del., as a research and development chemist.

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CARNEGIE, PENNSYLVANIA

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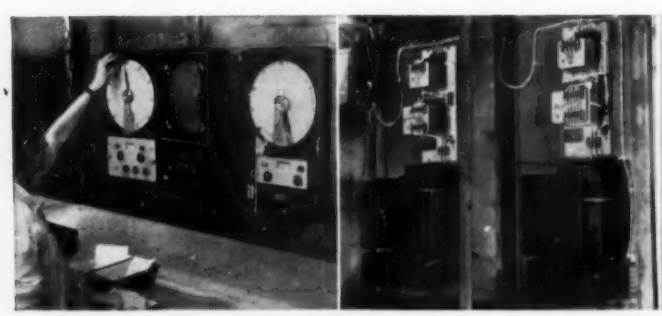

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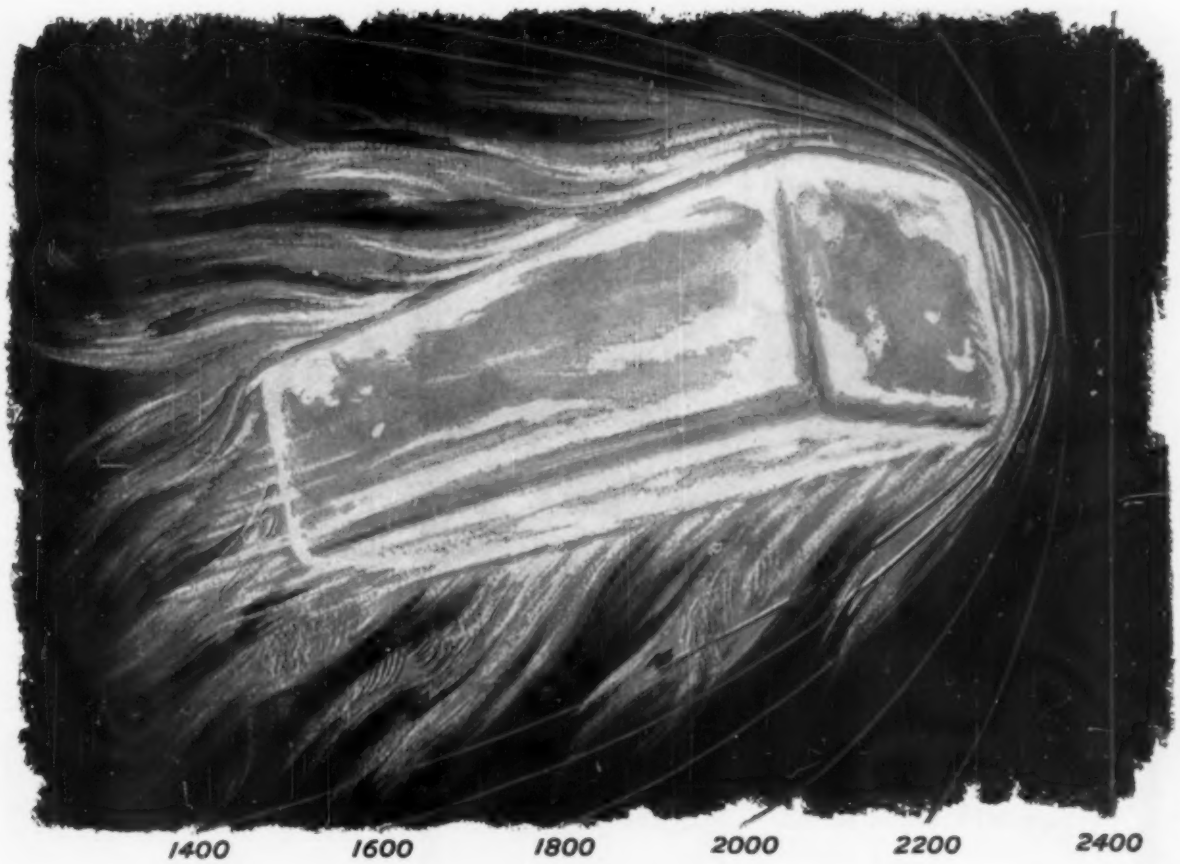
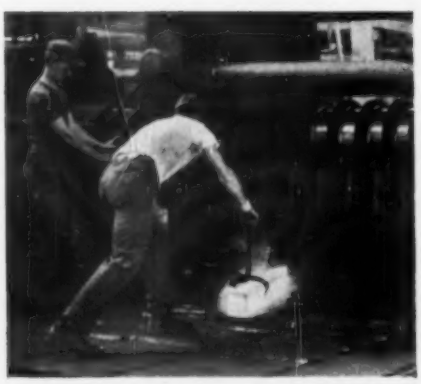


Bending the Heat Barrier



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DETROIT OFFICE: 23906 Woodward Avenue, Pleasant Ridge, Mich.

Personals . . .

Edward L. Shuck has been promoted to Chicago district sales manager for Haynes Stellite Co., Kokomo, Ind. Since joining Haynes in 1946, he has spent the greater part of his time in the Chicago district office, most recently acting as assistant district sales manager.

John S. Smart, Jr. has been appointed general sales manager of American Smelting and Refining Co., New York. Mr. Smart joined Asarco in 1936 as a metallurgist at the company's central research laboratories and rose to the position of assistant director of research, his last assignment prior to his promotion.

Peter Stefan has been appointed manager, mechanical alloys, for Wilbur B. Driver Co., Newark, N. J. Prior to joining Wilbur B. Driver Co., he held various managerial positions in the sales department of the Alloy Metal Wire Div. and Riverside-Alloy Metal Div. of H. K. Porter Co.

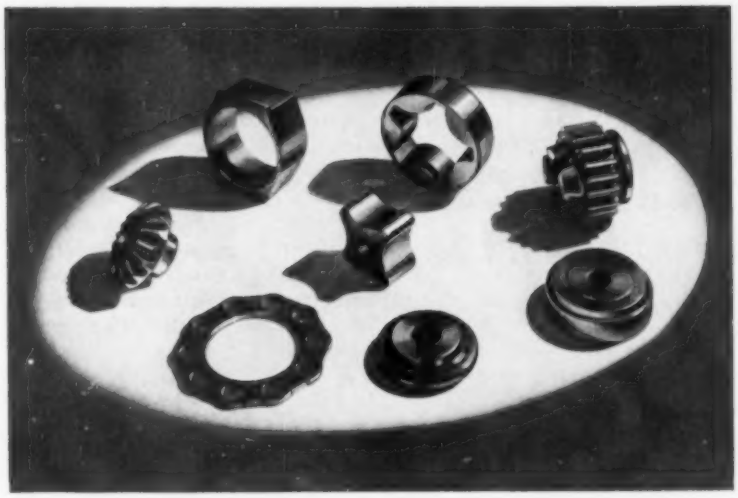
Arthur D. Schwartz is currently chief metallurgist for the White Sands Missile Range at White Sands Proving Ground in New Mexico.

Alan H. Braun has been assigned the position of director of quality control for Rosedale Foundry Corp., Hicksville, L. I., N. Y.

William C. Heidenreich was recently named manager of the St. Louis branch of Ziv Steel & Wire Co., Chicago.

William L. Grube has been promoted to assistant department head of the physics department of General Motors Research Laboratories, Warren, Mich. Mr. Grube joined the GM Research Laboratories in 1940 after his graduation from Ohio State University, and last held the post of supervisor of solid-state and fluid physics.

John A. Comstock has been named to head the Easton Metal Powder Co. research and development program to expand the use of atomized iron and steel for high-strength sinterings at the Easton plant in Easton, Pa., and at the Foote Mineral Co. Laboratories, and in Germany at Mannesmann's Research Institute.



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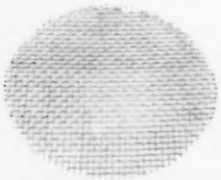

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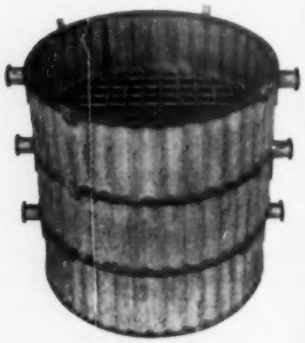

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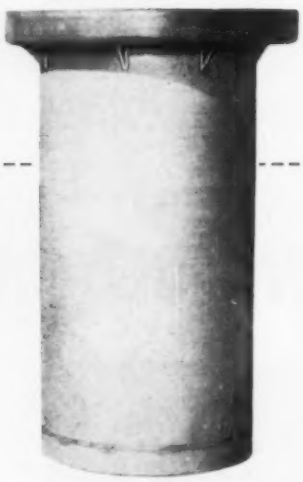

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Personals . . .

Robert S. Green, executive director of the Engineering Experiment Station at Ohio State University since 1954, has assumed new duties as associate dean of the College of Engineering. A professor in welding engineering and former chairman of the Department, he will retain his rank in welding engineering and will continue as executive director of the Experiment Station.

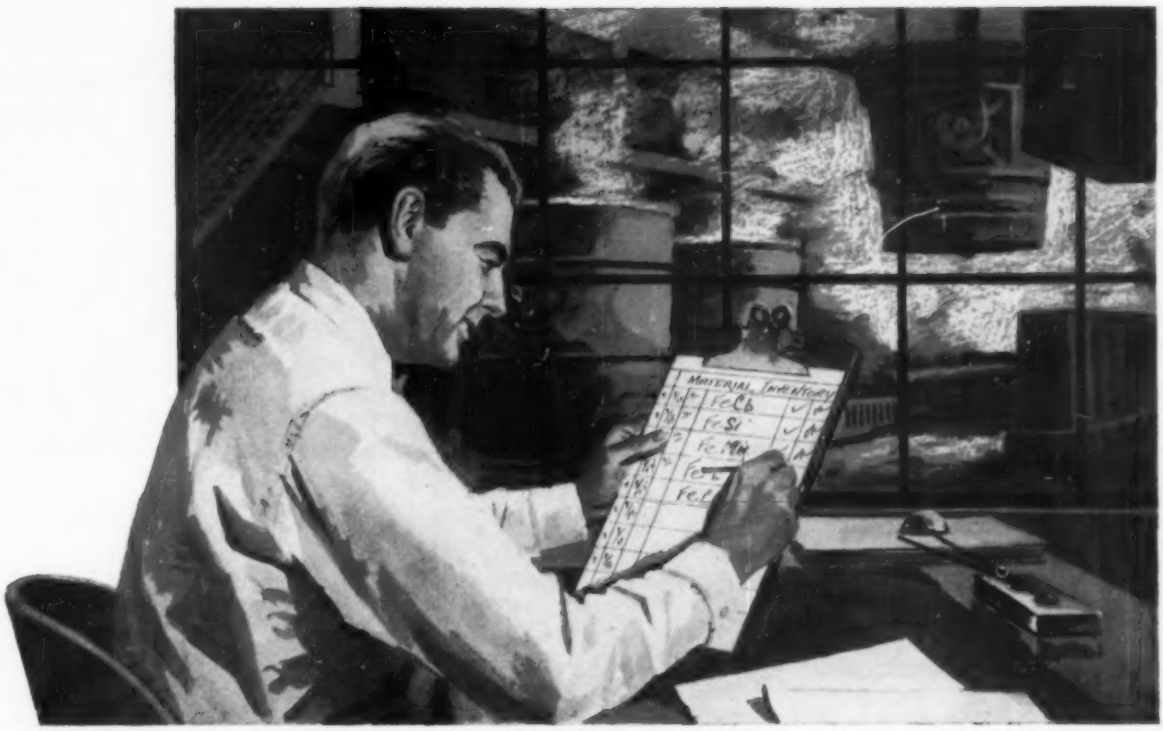
Franz H. Vitovec has been added to the faculty of the University of Wisconsin College of Engineering as associate professor of mining and metallurgy. He comes to Wisconsin from the University of Minnesota where he was associate professor in the department of mechanics and materials.

Charles Wurms, a recent recipient of a master's degree in metallurgy from Stevens Institute of Technology, has joined the staff of Argonne National Laboratories, Lemont, Ill., as a member of the plutonium section.

S. L. Weaver, district sales manager for Latrobe Steel Co. in Buffalo, N. Y., was recently transferred to Chicago as district sales manager. Prior to his position in Buffalo, he was district manager of sales in the Pittsburgh district.

G. Birger Olson, for the past six years consulting metallurgical engineer for Norden Instruments, Inc., Norden Laboratories Corp. and Norden-Ketay Corp., Milford, Conn., now is consultant for Norden Div. of United Aircraft Corp. Prior to becoming associated with Norden, Mr. Olson was for many years with General Electric and is the holder of G. E.'s top honor, the Coffin Award, for his work on the development of special alloys and treatment of alloy steels.

Ab Flowers has been appointed a development engineer for Crucible Steel Co. of America, Pittsburgh. Mr. Flowers joined Rem-Cru Titanium, Inc., then jointly owned by Remington Arms Co. and Crucible, as a research metallurgist in 1955. Rem-Cru came under Crucible's complete control early this year.



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Personals . . .

Alan E. King, promotions director for Clewiston Motor Co., Clewiston, Fla., will assume the post of parts manager when the company's new West Palm Beach branch is completed.

R. T. Eakin, manager of the Brackenridge, Pa., Works of Allegheny Ludlum Steel Corp., Pittsburgh, since 1951, recently resigned from the company.

William O. Wetmore has been appointed special assistant to the vice-president, Azusa operations, for Aerojet-General Corp. in Azusa, Calif. His background includes two years as vice-president and director of research and development for Hunter Engineering Co. and four years with the Hycon Mfg. Co.

Robert A. Eidam, a sales engineer for the Foundry and Mill Machinery Div., Blaw-Knox Co., Pittsburgh, has been transferred from East Chicago, Ind., to Brookfield, Wis., where he will be steel casting and fabricating sales representative for the company in Wisconsin, Minnesota, Upper Michigan and Iowa.

Walter H. Clemons has joined C. I. Hayes, Inc., of Cranston, R. I., as sales engineer. Prior to this, he was a design engineer for the industrial heating division of Westinghouse Electric Corp. in Meadville, Pa.

R. E. Kleint, formerly affiliated with North American Aviation, Inc., has been appointed vice-president and general manager of Ultrasonic Testing & Research Laboratory, Van Nuys, Calif.

Samuel W. Gearhart, Jr., has been promoted to chief metallurgist at Birdsboro Steel Foundry & Machine Co., Birdsboro, Pa. Since joining the company in 1956, he has served as sales engineer and more recently as metallurgical consultant and sales engineer.

Dale J. Richards was recently promoted to district manager in charge of the Detroit sales office of the Beryllium Corp., Reading, Pa. He joined the Reading firm in 1953 and most recently held the position of district representative in Detroit.

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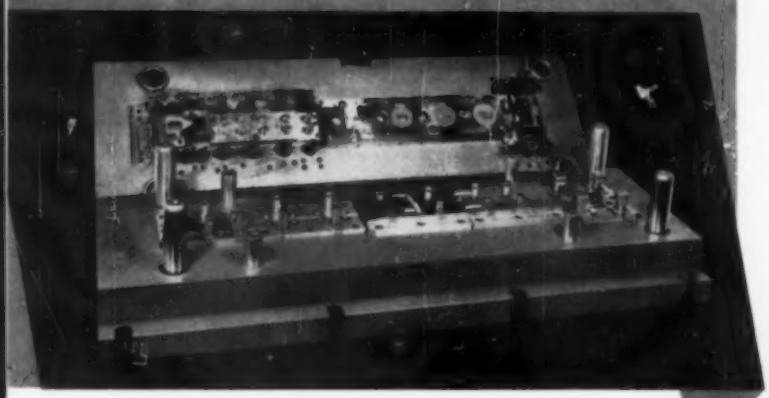

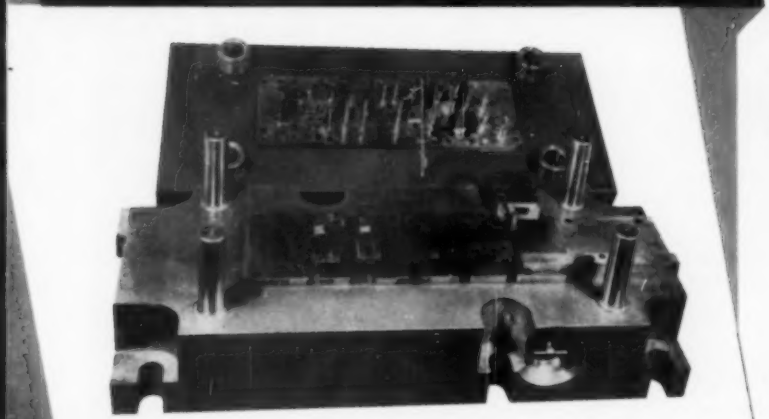

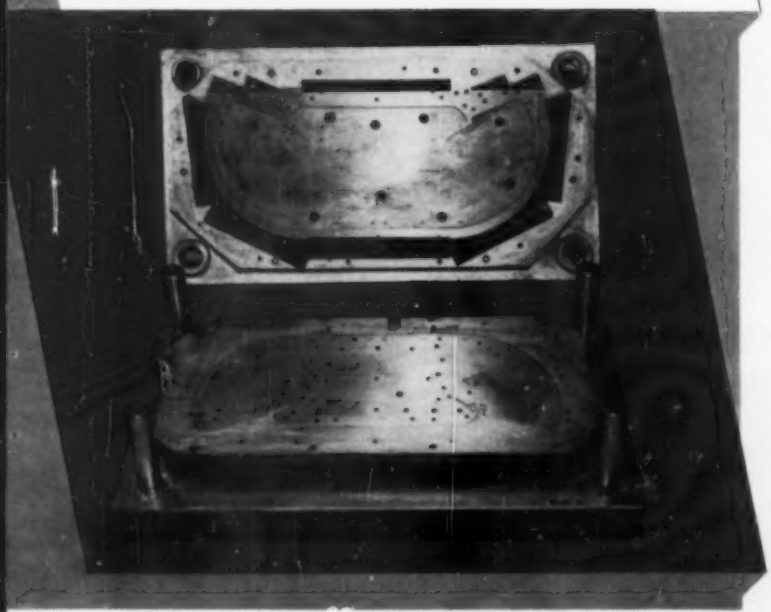

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AIR HARD Air hardening die steel having good machinability and exceptionally high strength and toughness. Movement in hardening about one-third to one-fifth that of oil hardening steels. Used for all types of cold work dies. Safe to harden, safe to grind. Available in regular or FM (Free Machining) types; also in precision ground flats and squares.

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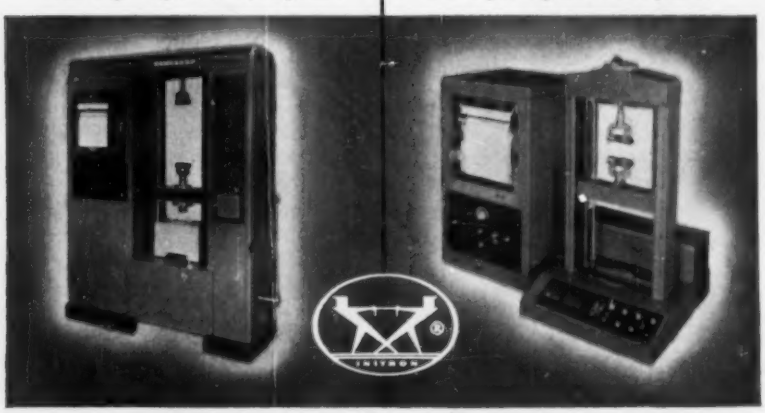

Personals . . .

J. Harris Phillips has been appointed sales representative of Universal-Cyclops Steel Corp. in the Cleveland district sales office, including the Toledo area. He was most recently with the Heppenstal Co.

Raymond O. Hallberg has been promoted to vice-president in charge of operations at Wilbur B. Driver Co., Newark, N. J. Since joining the company in 1933, he has held various supervisory positions throughout the company, including sales manager and general superintendent.

Wilson T. Groves has been named chief metallurgical engineer heading the engineering metallurgical department of Dana Corp., Toledo, Ohio. This department is responsible for metallurgical activities at the company's Auburn, Fort Wayne and Marion, Ind., Pottstown, Pa., and Toledo divisions. In addition, the department acts as metallurgical consultant to the Detroit, Chelsea, Mich., and Parish divisions, as well as to the Atlas Drop Forge and General Drop Forge wholly-owned subsidiaries and its affiliated Canadian plant, Hayes Steel Products, Ltd.

David J. Richards has retired as vice-president, sales, and director of E. F. Houghton & Co., Philadelphia. Mr. Richards served 41 years with Houghton, serving as assistant director of sales and a member of the Board of Directors before assuming his last position in 1945.

Louis H. Winkler has retired as metallurgical engineer with Bethlehem Steel Co., Bethlehem, Pa. Much of Mr. Winkler's work has been in rails, wheels, railroad products, wire and wire products, and piping and tubular products. He joined Cambria Steel Co. in 1909 after graduation from the University of Missouri and remained with that company through its consolidation with Midvale Steel and Ordnance Co. and its acquisition by Bethlehem in 1923.

Eric K. Foss has been appointed operating assistant to the executive vice-president of Copperweld Steel Co., Warren, Ohio. Prior to joining Copperweld, he was assistant chief metallurgist of A. M. Byers Co. in Pittsburgh.

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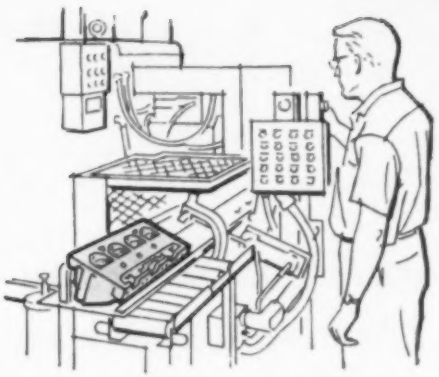

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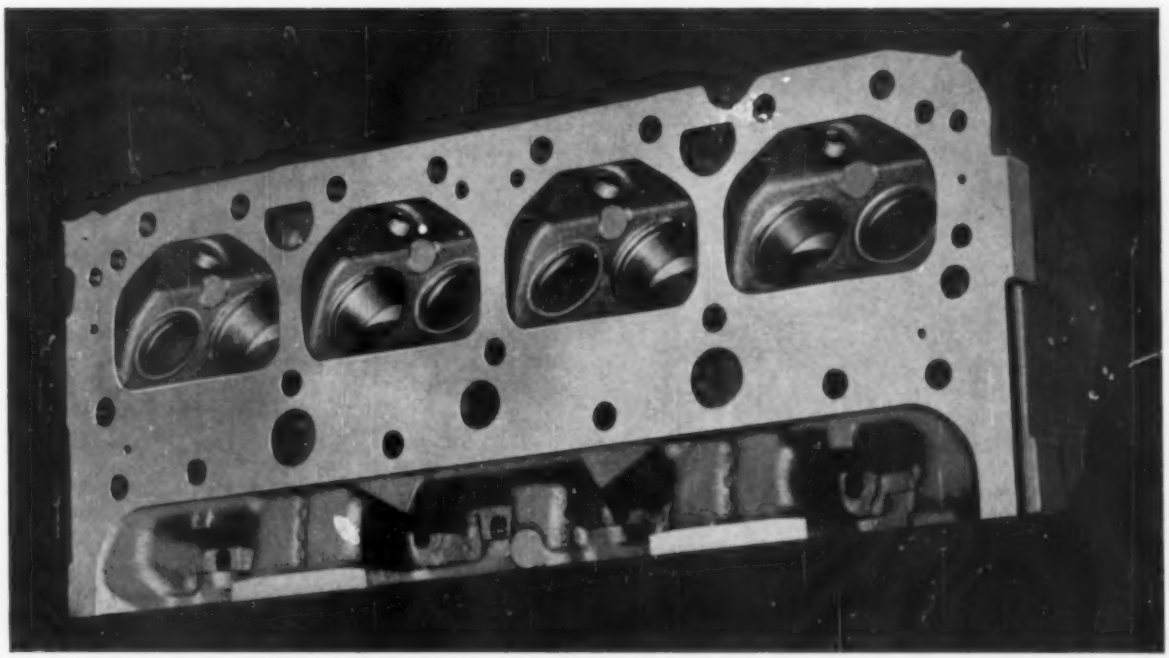

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Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Tempered Alloy Martensites

Digest of the Campbell Memorial Lecture, presented by P. Payson, Crucible Steel Co. of America, Pittsburgh, at the National Metal Congress, Cleveland, Oct. 30, 1958.

THE INTRODUCTION, early in this century, of high speed toolsteels which could machine while red hot revolutionized machining practices. Now, similar steels are being heat treated for red hardness to withstand the high temperatures produced by aerodynamic friction. These steels contain carbon, chromium, vanadium, tungsten and molybdenum in varying proportions depending upon their ultimate use. In all, red hardness (resistance to softening at elevated temperatures) is the unique property.

Red hardness is certainly associated with the formation and precipitation of alloy carbides when the martensite (formed on quenching) is heated. Before quenching, of course, the steel must first be heated to a temperature high enough to dissolve most of the alloying elements in the austenite.

Let us first consider the changes in hardness that occur in tempering three types of metals. Plain carbon martensite decreases in hardness continuously as the tempering temperature increases. In a precipitation hardening alloy which has been quenched and reheated, hardness remains constant over a range of temperature, rises to a maximum, and then drops. Finally, in a quenched high speed steel the hardness decrease parallels that of plain carbon martensite up to about 600° F. Then hardness rises to a peak or plateau at about 1050 to 1100° F. and drops fairly rapidly with further temperature rises. The increase in hardness over a 700 to 1050° F. range is generally referred to as "secondary hardening."

The over-all implication is that (in tempering an alloy martensite) there is first a gradual softening as in a plain carbon steel martensite, then a re-hardening because of a precipitation of alloy carbides. Though the reaction is complicated by retained austenite which may transform during the tempering operation, this does not affect red hardness greatly. As quenched, a hardened high speed steel may contain up to 20 to 25% untransformed austenite. When it is tempered twice (each period being 2 hr.) at 1050° F., virtually all retained austenite is transformed.

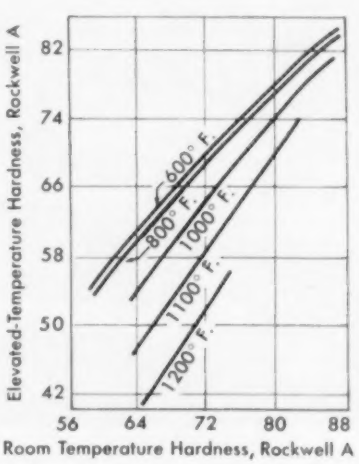

Fig. 1—Correlation of Room and Elevated Temperature Hardnesses for Tempered Alloy Martensites

High speed and hot work steels tempered to transform retained austenite have excellent resistance to softening.

Hot Hardness

There is a relatively simple relationship between room-temperature hardness and hot hardness of tempered alloy martensites. If the steel is tested at a temperature below the tempering temperature, its hot hardness will be directly proportional to its room-temperature hardness. This is shown in Fig. 1. in which are plotted data for a variety of tempered alloy martensites. The curves are roughly parallel indicating a fairly regular decrease in hardness with a 600 to 1200° F. increase. In other words, the higher the room-temperature hardness, the higher the hot hardness, provided the high-temperature testing does not affect the room-temperature hardness. A steel that has good red hardness therefore has good hot hardness.

Effect of Composition

As stated before, hardened and tempered high speed steels have higher hardness after lengthy exposures at 1000° F. than the hot work steel. Is this because of the difference in carbon content, differences in the alloying elements, or differences in both? As of now, this question can only be answered in a general manner.

The hardness of alloy martensites tempered into the fourth stage is definitely affected by both carbon and alloying elements. Since red hardness depends on the precipitation of alloy carbides, the steel must contain both carbon and carbide-

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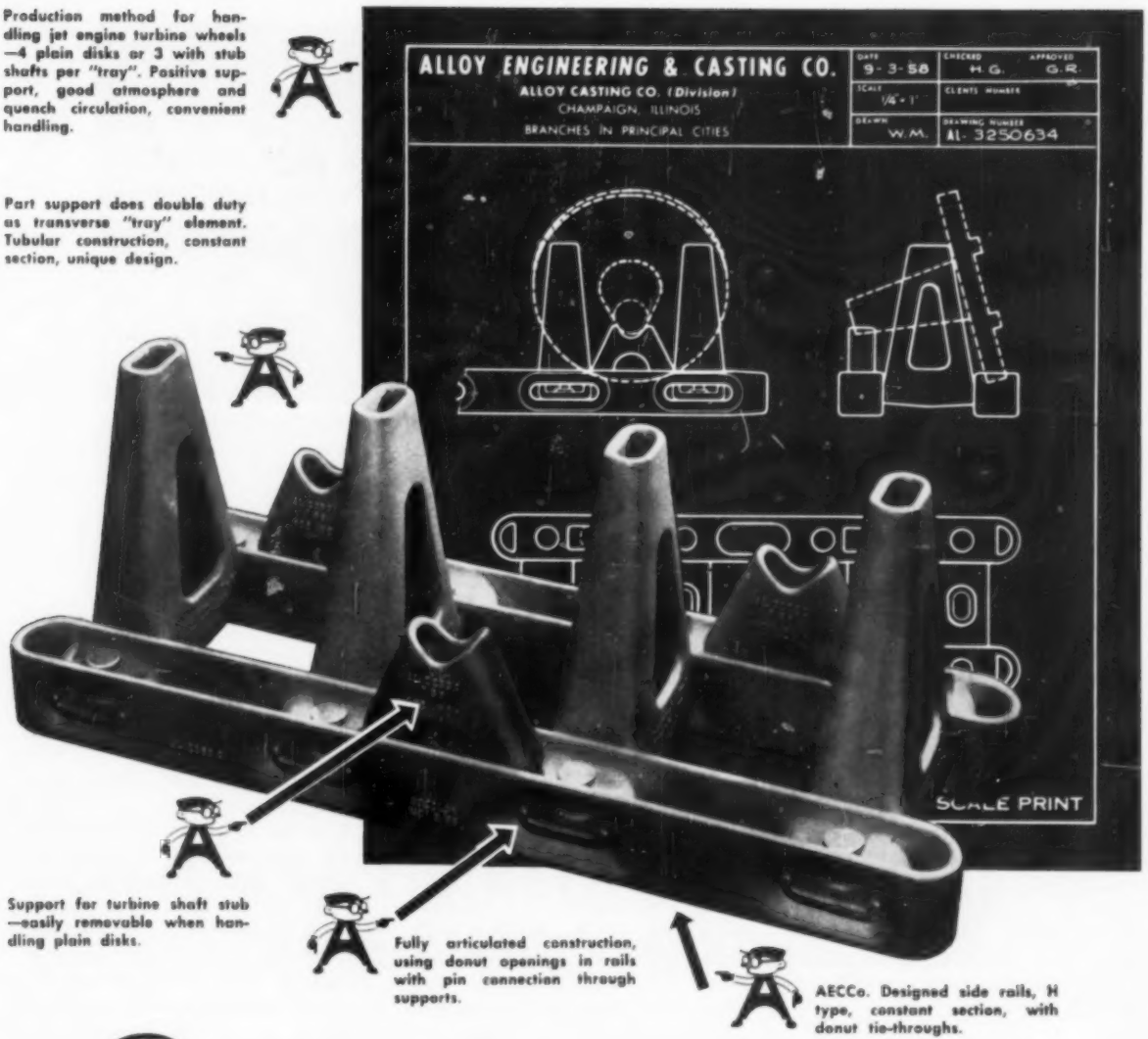
Part support does double duty as transverse "tray" element. Tubular construction, constant section, unique design.



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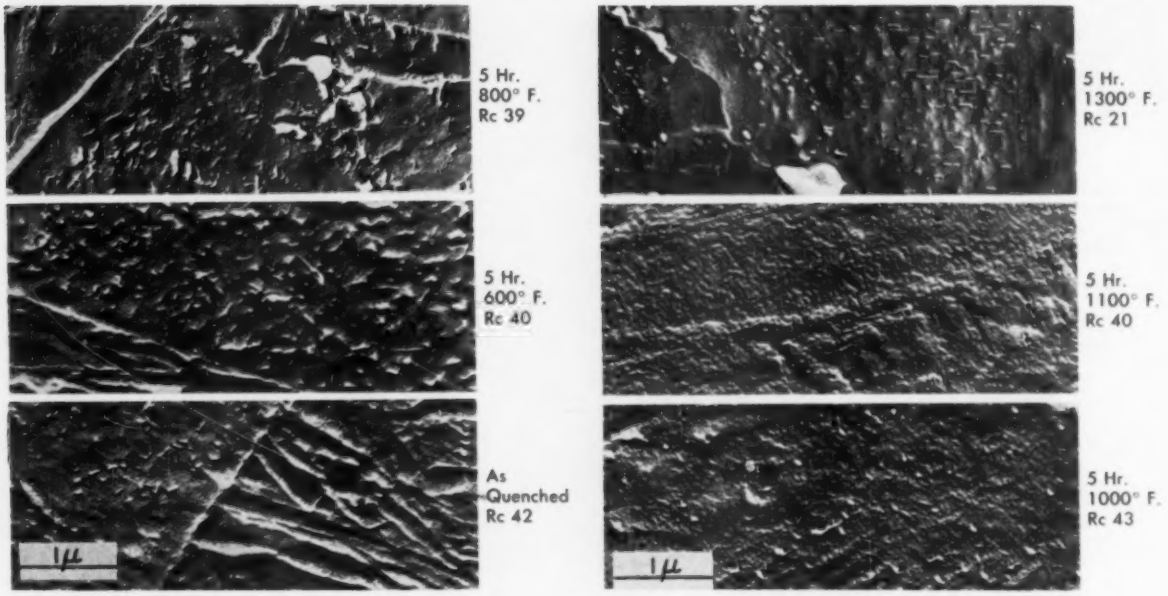


Fig. 2 – Electron Micrographs of a Low-Carbon Steel With 3.1% Mo (Samples Quenched From 2300° F. and Treated as Shown). Note emergence and growth of Fe_3C particles. Their subsequent disappearance at higher tempering temperatures is related to the formation of alloy carbides

forming elements. But the quantitative relationship between composition and hardness after tempering is not yet understood. The most interesting theory is that tempered hardness is dependent on the presence of Cr_7C_3, V_4C_3, W_2C, and Mo_2C, provided the steel has sufficient carbon to combine stoichiometrically with these alloying elements. If there is excess carbon, Fe_3C also forms and contributes to the hardness.

Some data supporting this scheme were obtained on a series of experimental steels, the compositions of which were designed so that the carbon and the carbide forming elements, chromium, vanadium, tungsten and molybdenum, would be present in approximately stoichiometric balance according to the quoted carbide formulas. The steels were heated between 2150 and 2350° F. (to dissolve the carbides), oil quenched, tempered at 950 to 1200° F. for times up to 32 hr. and tested for hardness. Though stoichiometric balances were not actually attained (since all samples contained residual carbides), the results are of considerable interest. They indicate that a "balanced" steel (one in which all the carbon present is combined with the alloying elements) is more resistant to softening than commercial high speed steels. As an example, a steel containing 1.1 C, 2.0 V, 4.6 W and 4.6 Mo needs about 3.2% Cr to "balance" the composition. Data for similar steels with excess chromium also indicate that the resistance to softening is lowered when the amount of alloying elements is more than that necessary to "balance" the carbon. Other data indicate that balanced relatively low-alloy steels are more resistant to softening than richer alloy steels. One would thus be inclined to conclude that "balanced" compositions would be ideal for steels for high speed and hot work tool applications, as well as for the steels with high strength at high temperature required for aircraft. However, the "balanced" steels are also generally less ductile during long-time exposures at 1000 to 1100° F. We are faced then with another question – how can we obtain both good red hardness and good ductility? This problem spurred us to undertake a more fundamental study of red hardness in steels.

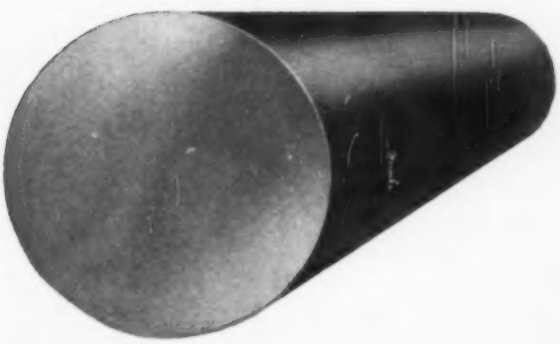
In our studies we used mainly a series of relatively low-carbon steels made in small induction heats and forged to about ⅝-in. square sections. Samples were austenitized at 2300° F. or higher, quenched in iced brine, and refrigerated in liquid nitrogen. They were then tempered over the range 600 to 1300° F. and tested for hardness, length changes, electrical resistivity and microstructure. Carbides precipitated during tempering were extracted and identified.

Microstructures

In some steels cementite, which forms during the third stage of tempering, gradually disappears (Fig. 2) under tempering conditions corresponding to the peak in the hardness curve, while in other steels cementite persists into the fourth stage and is still present after the alloy carbides have formed. In the molybdenum steel illustrated, cementite forms during tempering in a short time at about 500° F. and grows to sizable particles, then gradually redissolves and is completely absent in the sample tempered at 1100° F. for 5 hr. The alloy carbide, Mo_2C, was detected in the sample tempered at 900° F., and is found in all samples tempered at higher temperatures. Conversely in 0.7% V steel, cementite was present throughout the tempering range.

Start with a hole...

instead of a headache



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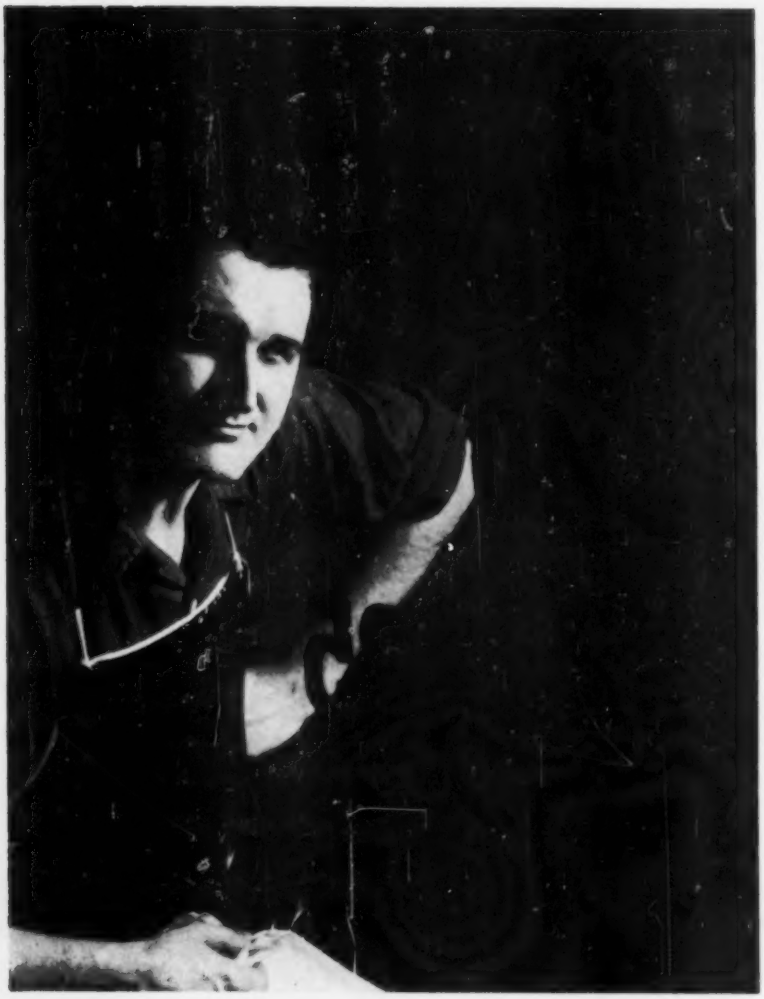

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Martensites . . .

Most of the identifications were done by electron diffraction. This technique obviates any interference from residual carbides because they are too coarse to be picked up by the replica or too thick to permit penetration of the electron beam. By matching up diffraction patterns, tempering conditions at which the alloy carbide appears and cementite disappears can be determined.

In Fig. 3 are shown changes in carbide which accompany the changes in hardness during the tempering of a tungsten steel. In this, as in most of the steels tested, the alloy carbide was detected at the beginning of secondary hardening, and cementite was present after the alloy carbide (W_2C) appeared. The M_6C carbide was also found after tempering above 1100° F.

Other data on carbides are also of interest. In the 5.8% tungsten steel both W_2C and M_6C were found in the samples tempered at 1200 and

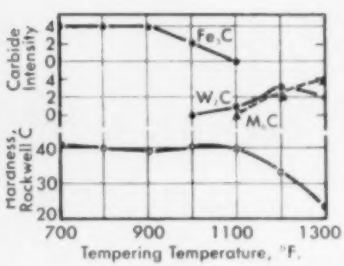
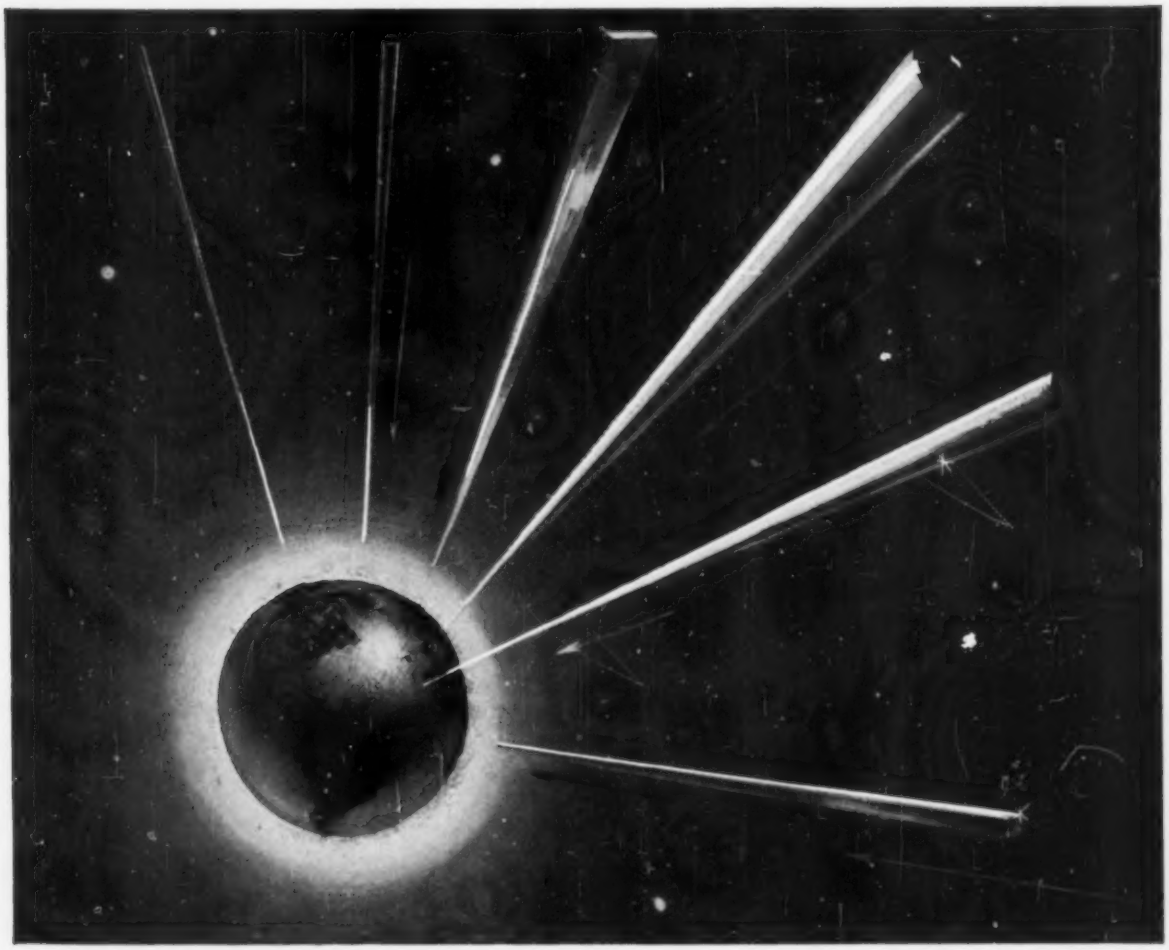


Fig. 3 – Comparison of Carbide Diffraction Patterns and Hardnesses of a 0.17% C, 5.8% W Steel Tempered 5 Hr. at Indicated Temperatures. As Fe_3C dissolves, alloy carbides emerge to maintain the hardness at a high level

1300° F., whereas only W_2C was found in the sample tempered at 1100° F. In the 0.14% C, 3.1% Mo steel, Mo_2C and M_6C were found after the 1300° F. temper, but only Mo_2C after the 1000, 1100, and 1200° F. tempers. In other molybdenum steels, only Mo_2C was found. In complex steels containing 0.9% or more of vanadium, the predominant precipitated carbide is M_4C_3, but in some of the steels the M_6C type is present along with M_4C_3.

The chemical analyses, though somewhat inaccurate for various reasons, have value in that they show



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(Instruments are made by Leeds & Northrup Co., and those shown here are in use at L&N's North Wales, Pa., plant.)

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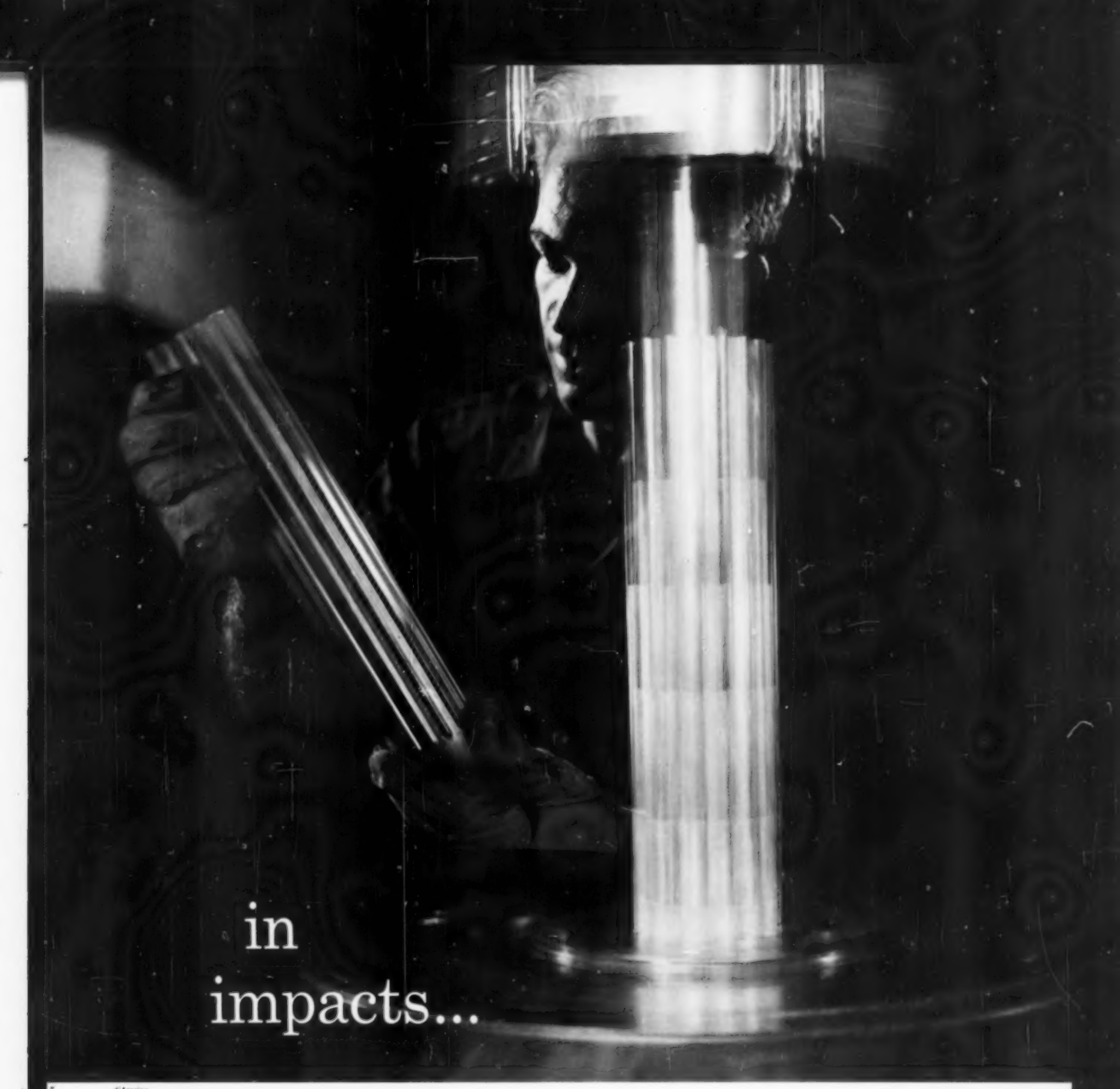
Martensites . . .

carbide composition changes during the tempering of the steels. The iron content decreased quite rapidly as the tempering temperature increased beyond about 900° F., indicating that the Fe_3C began to dissolve at about 800° F. after about 2 hr. Conversely, the alloy contents definitely increased as tempering exceeded 1000° F. for 2 hr., thus confirming that the alloy carbides formed under these tempering conditions. Data show that secondary hardening is definitely associated with the first precipitation of the alloy carbide.

Electrical resistivity decreases gradually up to about 1000° F. during the period when cementite separates from the matrix and then more rapidly as the matrix becomes depleted in the alloying element. The X-ray diffraction lines are quite broad up to about 1100° F.; this indicates a strained condition of the matrix. Above this temperature, the lines sharpen indicating a relaxation of the strain. Finally, precise length measurements made at room temperature before and after tempering indicated a decrease in length during the early tempering stages followed by an increase during the initiation of alloy carbide precipitation. The contraction during the third stage was expected but the increase in length accompanying the secondary hardening was surprising. We believe this unexpected expansion is not necessarily attributable to the transformation of retained austenite. In one test a small quantity of austenite was found in the as-quenched samples but after the 500° F. temper, examination by X-ray diffraction indicated that no austenite remained.

The length-change data indicate an expansion up to 500° F. (attributable to retained austenite transformation). This is second stage tempering. The contraction between about 400 and 900° F. is attributable to the separation of cementite from the matrix – the third stage of tempering – and this contraction is greater the higher the carbon content of the steel. The expansion between about 900 and 1200° F. we believe is due to straining of the matrix by the formation of a coherent precipitate of the alloy



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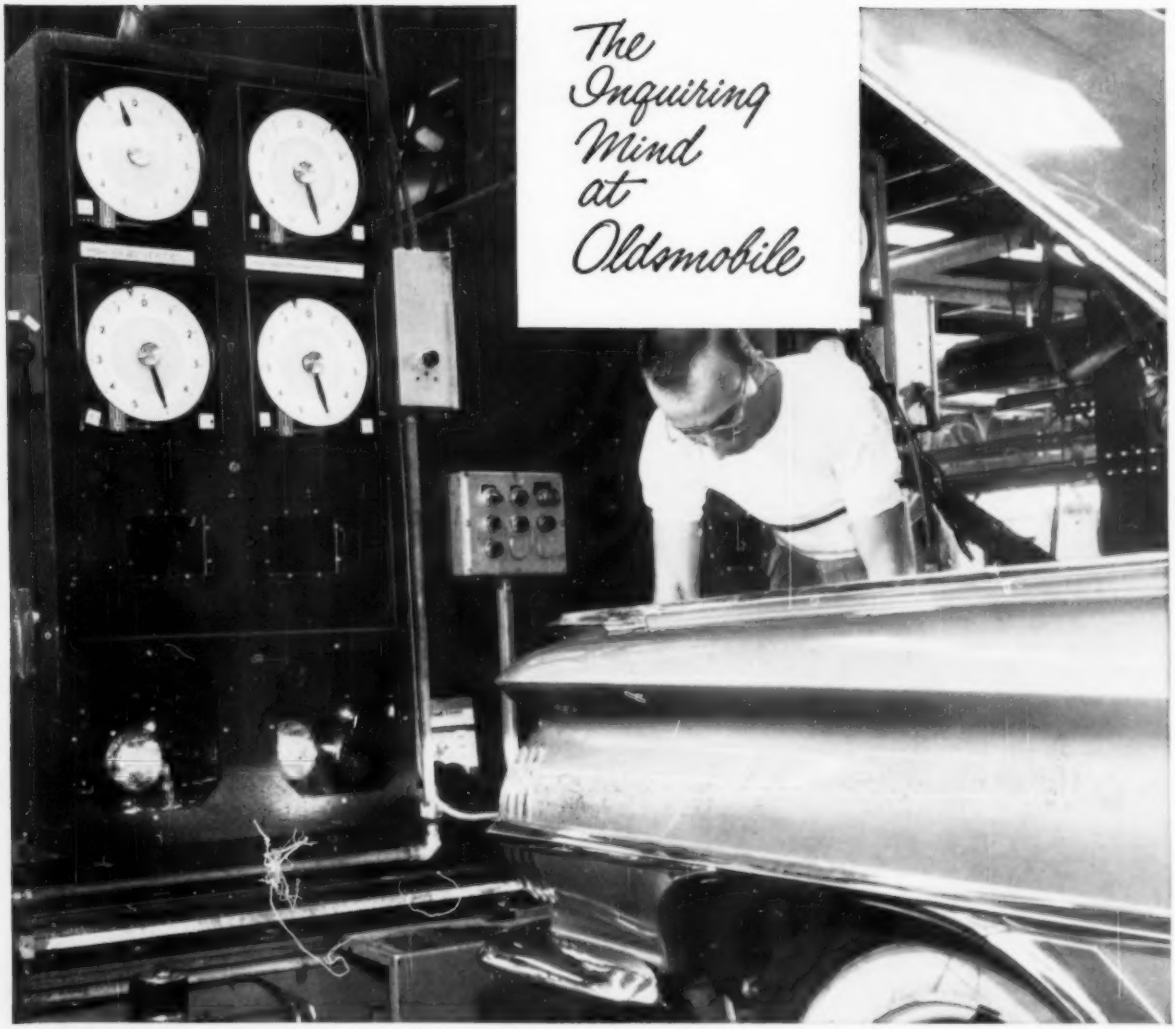

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Martensites . . .

carbide. Once coherency is lost as the alloy carbide grows with increase of tempering temperature, there is no longer a state of strain and the steel again begins to decrease in length with further tempering.

Conclusions

And so we have arrived at the conclusion that secondary hardening is attributable to a coherent precipitation of alloy carbides, and that these carbides may be one of several types depending on the composion of the steel. The iron carbide (Fe_3C) may also be present up to and beyond the secondary hardness peak. Red hardness is attributable to the gestation period in the development of the precipitated alloy carbide. Where chromium is the only carbide-forming element, there is no real secondary hardening although there is considerable resistance to softening during relatively short-time tempering up to about 900° F.

Although the concept of separate alloy carbides for the four carbide-forming elements has not been substantiated, its use has helped us develop steels of superior resistance to softening. It appears that the gestation period in the development of the precipitated alloy carbide is prolonged when there is a certain balance between the carbon content and the alloy content of the steel.

Several questions remain unanswered. All good teachers are willing to concede that they do not know everything about the subjects they discuss and are generally content to point out directions for the curious ones to travel. I believe Professor Campbell would have approved of this, so here then are these questions:

1. What formula should be used in balancing carbon and alloy contents for a desired hardness after a specified tempering procedure?
2. What compromise must be made in this formula to provide good ductility along with good hardness?
3. Under what circumstances does cementite persist in alloy steels throughout the tempering range?
4. Can we establish whether the carbon content of the matrix is actually increased during the secondary hardening period, or whether carbon

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Martensites . . .

(redissolved from precipitated Fe_3C) immediately combines with alloying element and precipitates as alloy carbide? If the carbon content of the matrix does increase, this would help account for the expansion that occurs during this period.

5. What are the limits of the alloy contents of the carbides precipitated during tempering?

6. Why does not the precipitation of chromium carbide in plain chromium steels cause any secondary hardening?

7. In what way does cobalt contribute to the red hardness of alloy steels? (I have carefully avoided this subject because very little is known about it.)

8. When hardened high speed steel is tempered, the retained austenite is said to be "conditioned" by heating at 1050° F. to transform to martensite during subsequent cooling. This conditioning mechanism has not been adequately explained.

Although we expect that others working in this field will answer some of these questions, we shall continue to study alloy martensites and some day we may fully understand them. C.R.W.

Turbogenerator . . .

(*Starts on p.* 114)

defined bands suggesting that it had been bombarded by solid particles traveling at high speed; these bands, and the normal clean machined surface of the valve tail are identified also in Fig. 1.

Since this suggested damage by hard particles entrained in the steam, samples were taken of the solid material entrapped in the top and bottom strainers, of particles adhering to the valve bushings and shafts, and of material actually embedded in these components. These were analyzed chemically, metallurgically and spectroscopically. The predominant component appeared to be fragments of chilled iron which formed the nuclei of agglomerations of metal mainly derived from the valve spindles and bushings. There was also evidence that chilled iron was present on the seized parts of

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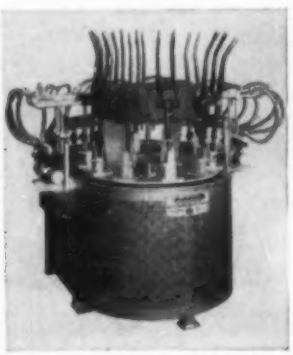

Two fork styles in all standard bicycle sizes are joined from eight steel components on this new automatic Selas machine by Westfield Manufacturing Co., Westfield, Mass. Controlled combustion and flame geometry bring the parts to brazing temperature of 1750°F in only 86 seconds, using economical Gas equipment.

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IT BENDS WITH THE HEAT

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Turbogenerator . . .

the governor valve. Direct comparisons were therefore made with samples of chilled iron shot taken from the last consignment supplied to the site approximately six months previously.*

The fragments of recovered and embedded iron were found to have an identical dendritic structure to the control sample of shot, and a similar diamond penetrator hardness of 850 DPH. Vanadium, titanium and other trace elements were detected spectroscopically in both the material recovered and the control sample. Surface layers of metal were removed from the spindle of the runaway stop valve by electropolishing, after which some embedded particles were isolated. Three particles of shot were identified by microstructure and by hardness. Figure 2 clearly shows the different metallographic structure of an embedded particle and the surrounding material.

As further confirmation of the theory that the materials found in the valve unit were foreign to the system, the investigating committee heard that no metals were used in the steam system of a hardness greater than about 350 DPH. They therefore concluded that the markings on the spindles indicated that they had been abraded by fine hard particles entrained by steam and entering clearance spaces, and that the foreign bodies which jammed the two valves were fragments of chilled iron shot.

Origin of the Shot

From the appearance of the spindle of the governor valve, and the presence of shot in the steam strainers of the valve unit, it was concluded that these particles had been carried into the valves by the steam system. The size of the fragments in relation to the clearances between spindle and guide were completely consistent with such a conclusion. Several components of the system were known to have been shot-blasted but the investigating committee was unable to obtain any

(*Continued on p.* 152)

*EDITOR'S FOOTNOTE—Presumably this was used on the site in hand guns to clean up various items of piping and other equipment prior to erection.

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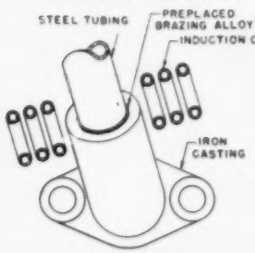
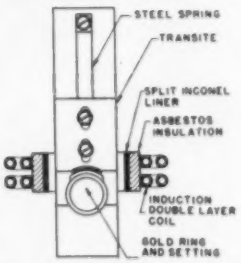


Assembly of iron castings and steel or copper parts are facilitated by induction heating. Arrangement is illustrated for silver brazing malleable iron castings to steel tubing. Coil design shown provides uniform heating for joint. Proper joint design assures high bond strength. Electrolytic treatment of castings to remove carbon (Kolene Treatment increases strength and tightness of joint to gases and liquids.

GOLD BRAZING IN JEWELRY INDUSTRY



Liner type induction coil shown provides a flexible arrangement for brazing settings to gold rings. The simple fixture facilitates handling. The unique coil design permits heating by induction and by radiation from heated metal liner. Ring, setting and gold brazing alloy are pre-assembled in a ceramic jig and then moved into heating position within the coil for brazing.

CUTTER BLADES SELECTIVELY HARDENED

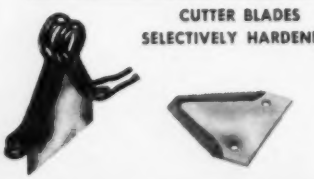


Photo shows coil design and arrangement used to selectively harden edges of cutter blades used in agricultural equipment. In production, cutter blades are automatically fed between layers of the induction coil, selectively heated and then oil quenched at the rate of one per second. Hardness at the cutting edge is Rc 62/64. Distortion is negligible.

Electronic Tube Generators from 1 kw to 100 kw.
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Turbogenerator . . .

direct evidence as to how shot might have entered the steam system. One obvious conclusion was that steam plant in the future should be carefully examined before commissioning to make sure that it is free from shot, dirt or other deleterious material.

Steam Boilers Versus Atomic Reactors

It thus became apparent that the generator failed through gross overspeeding, and this in turn was the result of nonfunctioning "automatic" auxiliaries. (It is worthy of note that the first intimation of danger came not from the turbogenerator but from the reactor – the heat producing unit.) Fortunately, flying fragments or any other associated train of events did not damage other parts of the power plant. This might have led to serious trouble in a conventional coal-fired boiler plant, but could have been even more dangerous at Calder Hall where the heat comes from atomic reactors. An important portion of the investigating committee's report therefore has to do with the somewhat unique design features of the entire plant. These are of most interest to the power plant engineer, but brief mention may be made for those who are interested in peaceful uses of atomic energy.

It will be recalled that the Calder Hall plant is one of a series of power-producing units being constructed to deliver electricity into the general industrial network. Its reactors use natural uranium for fuel, graphite for moderator, and CO_2 gas for coolant. Each reactor has four heat interchangers receiving CO_2 gas at 640° F., and generating steam at 590° F. and 210 psi. Thus any radioactivity in the gas coolant is retained in the primary piping system; the steam generated and passing to the turbines should be free.

At Calder Hall the reactor control rooms are on the turbine-house side of the reactors, and there are two strong structural walls protecting the control room, which of course are desirable.

Because of the layout of the plant, it was unlikely that more than two heat exchangers would be damaged by a turbogenerator accident. The

how standard AISI-SAE MOLY CARBURIZING STEELS help Pontiac 3 ways

After extensive testing, Pontiac adopted the 4520 type for ring gears and pinions in its 1956 model and has used this grade ever since.

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AISI-SAE 4520 is more economical than the previously used carburizing steel with lower molybdenum content.

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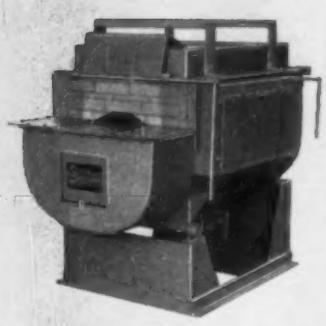
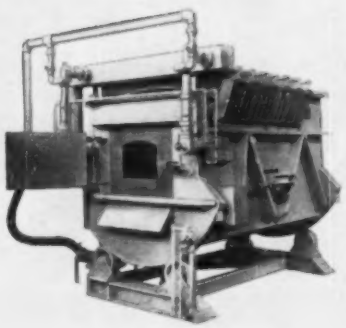
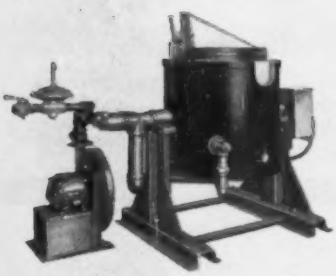


Electric Resistance Holding Furnace—Available in several capacities for holding molten aluminum for die casting and permanent mold work.

Reverberatory Furnaces — for breakdown of non-ferrous metals to supply hot metal to holding furnaces. Can be supplied with gas or oil or combination burners. Hydraulic tilting mechanism. Also available are double chamber furnaces for melting and holding in the same furnace.





Crucible Melting Furnaces — for brass, bronze, aluminum and other non-ferrous metals. Stationary or tilting may be tilted manually, hydraulically, mechanically, or by independent hoist. Wide range of sizes.

The Stroman Furnace and Engineering Company, manufacturers of non-ferrous metal melting furnaces and other foundry equipment, has been purchased by Hevi-Duty Electric Company.

The wide range of Stroman-designed foundry equipment will now be produced at Hevi-Duty's new Watertown, Wisconsin, plant. All Stroman equipment now in use will be serviced by Hevi-Duty. For more information, write Hevi-Duty Electric Company, Milwaukee 1, Wisconsin.

- Industrial Furnaces Electric and Fuel
- Laboratory Furnaces
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HEVI-DUTY ELECTRIC CO.
Milwaukee 1, Wisconsin

Turbogenerator . . .

gas circuit to each heat exchanger is independent, and could be isolated by valves situated behind thick concrete walls. In the event of damage to the gas ducts, the reactor would trip automatically; if not already tripped, the valves in the affected circuits could be closed. The committee therefore concluded that damage to the gas duct would not cause any hazard to the reactor.

One of the consequences of the accident was that water from fractured mains flowed from pipe trenches to cable ducts and some of the main electrical equipment had to be withdrawn from service. Appropriate barriers should be installed in cable ducts, and pipe trenches should be adequately drained. As a further precaution, it was recommended that the intakes to the air-cooling system for the biological shield should be so placed as to insure that they could not become immersed during any accidental flood.

Although the accident involved no release of radioactivity, the committee considered possible secondary consequences which might have arisen, and reached the conclusion that the reactor itself had not been put in any danger.

Testing Adhesive Strength of Metallic Coatings

Digest of "Improved Methods of Testing the Adhesive Strength of Metallic Coatings on Wires", by E. A. Franks, *Metalloberflache*, Vol. 11, February 1957, p. 53-59; abridged in *Engineers' Digest*, Vol. 18, April 1957, p. 151-152.

THE USUAL TECHNIQUE for testing the adhesive strength of metallic coatings on wire is to wind a length of the coated wire around a mandrel about eight to ten times the diameter of the wire and to note whether the coating flakes off or is otherwise damaged. This test does not reflect a durable adhesive strength under conditions such as fatigue or impact. Hence other and more stringent methods of deformation have been devised.

By mounting a measured length of wire in the jaws of a conventional

torsion testing machine and observing the number of complete revolutions before the first loosening or flaking of the coating occurs, adhesive strength in torsion can be compared among different specimens. Uniformity of results will depend upon a constant length of wire and rate of twisting.

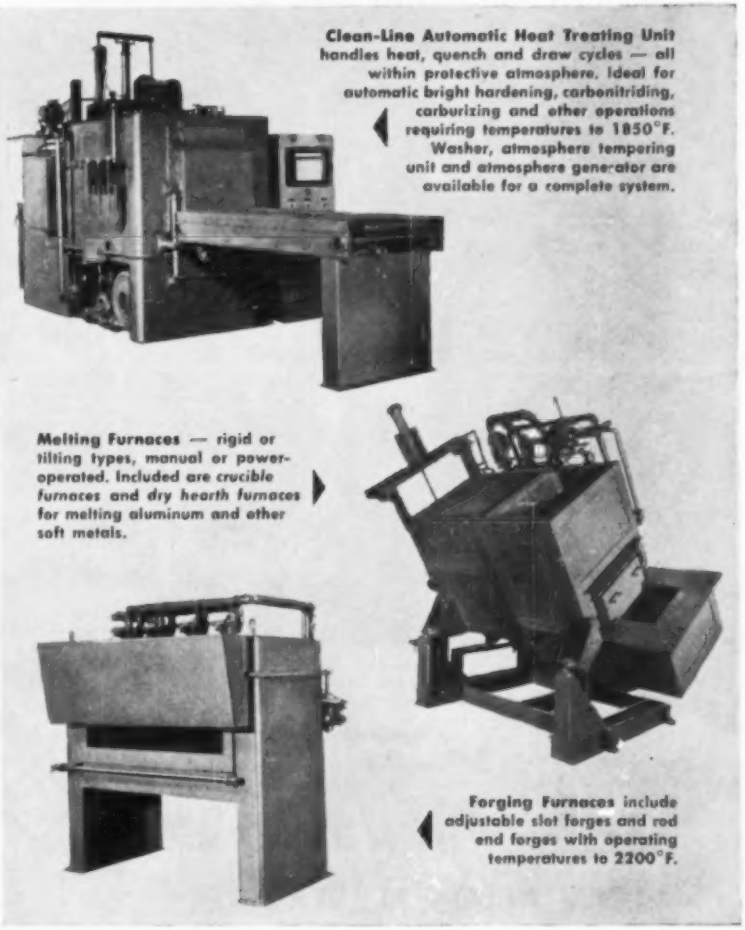
In another test a wire sample is fed between two cylindrical rolls with variable center distance to permit adjusting rolling pressure. One roll is driven at slow speed or turned manually. The test is carried out at intermittently increased pressures or with repeated passes at increasing pressure. The pressure at which the first particles of coating flake off completely can be taken as a comparative measure or index of adhesive strength.

In a bending test under tension, the wire sample is held between two clamps and is bent by pressure applied through a grooved plate or disk guided transversely to the axis of the wire. The disk is pressed against the wire until the first particles of coating flake off on the more highly stressed tension side of the wire. The deflection obtained constitutes an excellent measure of coating adhesion.

In a refinement of the winding test, a conical drum makes it possible to vary the degree of flexing of the wire as it is wound from the larger diameter down to the smaller diameter of the drum. The wire may be guided by grooves cut in the drum surface or by a guide traveling on a feed screw. Weights on the free end of the wire maintain tension to keep it firmly on the surface during winding and to straighten it out in unwinding. The number of winding and unwinding cycles at which the first signs of flaking occur is a measure of adhesive strength of the coating. Diameter of the drum at the point where flaking is first observed must be indicated as a measure of the stress imposed. Suggested dimensions of a drum are 3 ft. long, with maximum and minimum diameters of 16 in. and ½ in., respectively.

This test can be simplified and accelerated if two drums are positioned next to each other and the wire wound first on one, then unwound onto the other. Each complete winding cycle thus stresses the

HEVI-DUTY ANNOUNCES
the addition of fuel-fired furnaces to its line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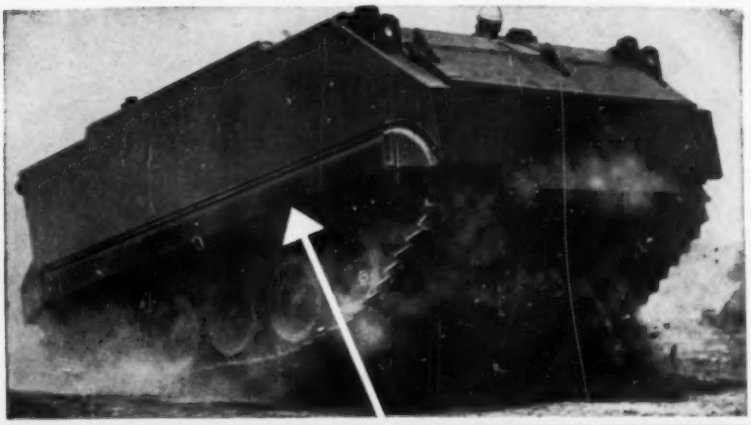
How to produce low alloy welds to resist tons of torture



Job Report Courtesy of
Food Machinery and Chemical Co.
Ordnance Division, San Jose, Calif.

WELD WITH ARCOS

LOW ALLOY ELECTRODES

This 22½ ton armored personnel carrier proves an important point. When working with hard-to-weld low-alloy plate, and welds must be extra strong and tough in the "as welded" condition, it pays to use the highest quality weld metal available. In this case, Arcos Tensilend 100, a low hydrogen coated electrode produced weld metal that matched the physical and chemical properties of the base metal. In addition, it did the job with less nickel than the 19-9 modified electrode formerly used. There was no preheat, no postheat . . . and complete freedom from cracking. ARCOS CORPORATION, 1500 S. 50th St., Philadelphia 43, Pa.

Adhesive Strength . . .

wire twice. If the drums are placed with the smaller diameter of one opposite the larger diameter of the other, winding stresses will be unequal; if their positions are reversed, stresses can be made equal.

Coatings subject to impact in service can be tested by a simple pendulum-type hammer striking the wire, or by a hammer actuated by a ratchet device. The wire can either be stretched flat on a plate or wound on a rotating disk. The number of hammer blows required to induce flaking is a measure of the adhesive strength. ARTHUR H. ALLEN

Magnox—Corrosion Resistant Magnesium

Digest of "Progress on Specific Reactor Types — Calder Hall and Related Types", *Power Reactor Technology*, December 1957. [The first issue of a quarterly review of recent developments prepared by General Nuclear Engineering Corp. (W. H. Zinn), for the U.S. Atomic Energy Commission. Subscriptions $2 per year.]

AS IS WELL KNOWN, the British power reactor at Calder Hall uses a natural uranium fuel element, cooled with CO_2 gas, and moderated with graphite. Among the many design problems were the development of materials of low absorption for use in CO_2 at high temperature, a design of fuel slug to achieve the necessary heat transfer rates, and the fabrication of pressure vessels of sufficient size to contain the reactor.

An article by Tom Bishop in *Metal Progress* for June 1957 describes the jacketing or canning. Oxidation resistance at operating temperatures was of course important. Tests in dry CO_2 at 8 atm. pressure and 750° F. for five months gave the following losses:

No measurable attack: 18-8-1 stainless, commercial aluminum, sintered aluminum powder.

Loss 0.1 mg. per cc.; commercial magnesium, "Magnox C".

Loss 0.15 to 1.10 mg. per cc.; age hardened aluminum, strong magnesium alloys, steel (mild and low-alloy), sintered magnesium powder.

More than 2 mg. per cc.; cast iron.

Magnesium was chosen for its good resistance to corrosion and high heat conductivity. Mr. Bishop's article recounts how various "Magnox" alloys were developed by Magnesium Elektron, Ltd., containing aluminum, beryllium and calcium. Preferred analysis (Magnox C) has 0.7 to 0.9% Al, 0.005% Be and no Ca, made with 99.95% Mg.

Ignition tests on Magnox alloys revealed an ignition temperature of approximately 1200° F. at 11 atm. pressure of CO_2 for all variations. No ignition occurred at temperatures up to 1300° F. with CO_2 at atmospheric pressure and at a flow rate of 20 cu.ft. per hr.

The Magnox alloys are extremely sensitive to metallic contamination.

High-temperature tensile tests on Magnox C at a strain rate of 18% per in. gave the following results:

212° F.	12,800 psi.	8% elong.
400	6,200	23
575	3,000	53
750	1,000	88

Time for rupture at 660° F. under various creep strains and stresses gave the following data:

Time	Stress	Creep Strain
35 hr.	800 psi.	36%
115	700	26
220	600	22
580	500	30
1460	400	52
2200	300	25

E.E.T.

Strain Aging of Steel Sheet

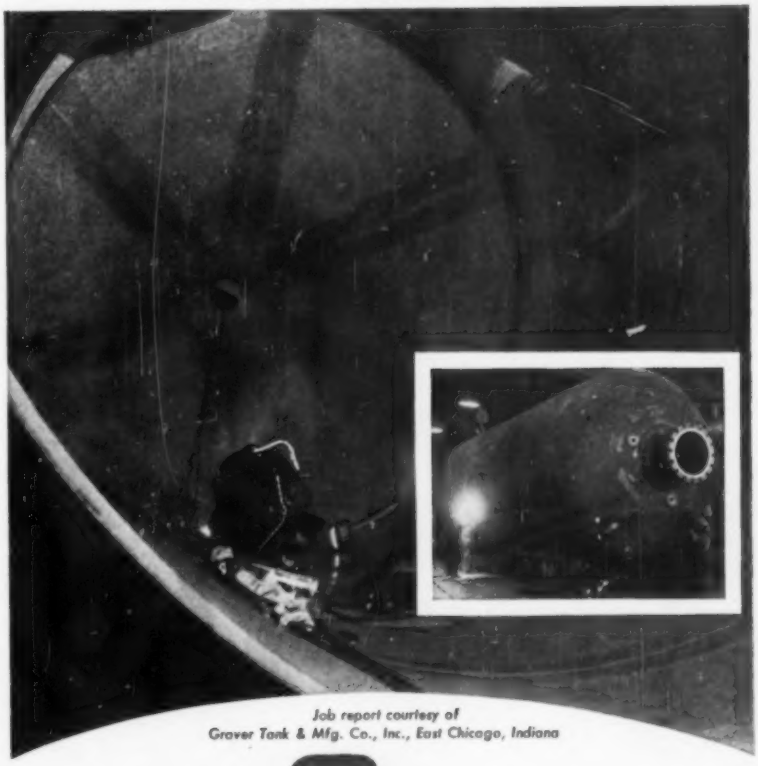
Digest of "Some Observations on the Aging of Low-Carbon Steel Sheet", by E. R. Morgan, Jones & Laughlin Steel Corp., S.A.E. Preprint No. 30A, March 1958, 10 p.

THE STRAIN AGING of steel sheet to be used for automobile pressings results in the formation of stretcher-strain markings or Lüder's bands, and sometimes causes serious loss of ductility. Efficient control of the phenomenon is difficult without a complete understanding of the mechanism of yielding and aging.

The formation of the bands is associated with the yield point phenomenon in steels. The accepted theoretical explanation of this phenomenon, and the effects of cold

(*Continued on p. 160*)

When stainless welds must be free of microcracks



Job report courtesy of Grover Tank & Mfg. Co., Inc., East Chicago, Indiana

WELD WITH ARCOS

STAINLESS ELECTRODES

This 93,400-lb. 3500 cu. ft. digester is installed at Finch, Pruyn and Company, Inc., manufacturers of printing and converting papers. It converts hardwood into paper pulp using highly corrosive acids at high temperatures, and pressures of 200 psig. The digester is made of Type 316 ELC 20% stainless clad on ASTM A-212 Grade B firebox steel. To assure sound, long-life corrosion-resistant welds, three grades of Arcos CHROMEND Electrodes were used. All welding was manual. The resultant welds were completely free of micro fissures or cracks—more proof why Arcos weld metal is used so widely to combat destructive and costly corrosion. Write for an Arcos Stainless Application Chart. ARCOS CORPORATION, 1500 South 50th Street, Phila. 43, Pa.

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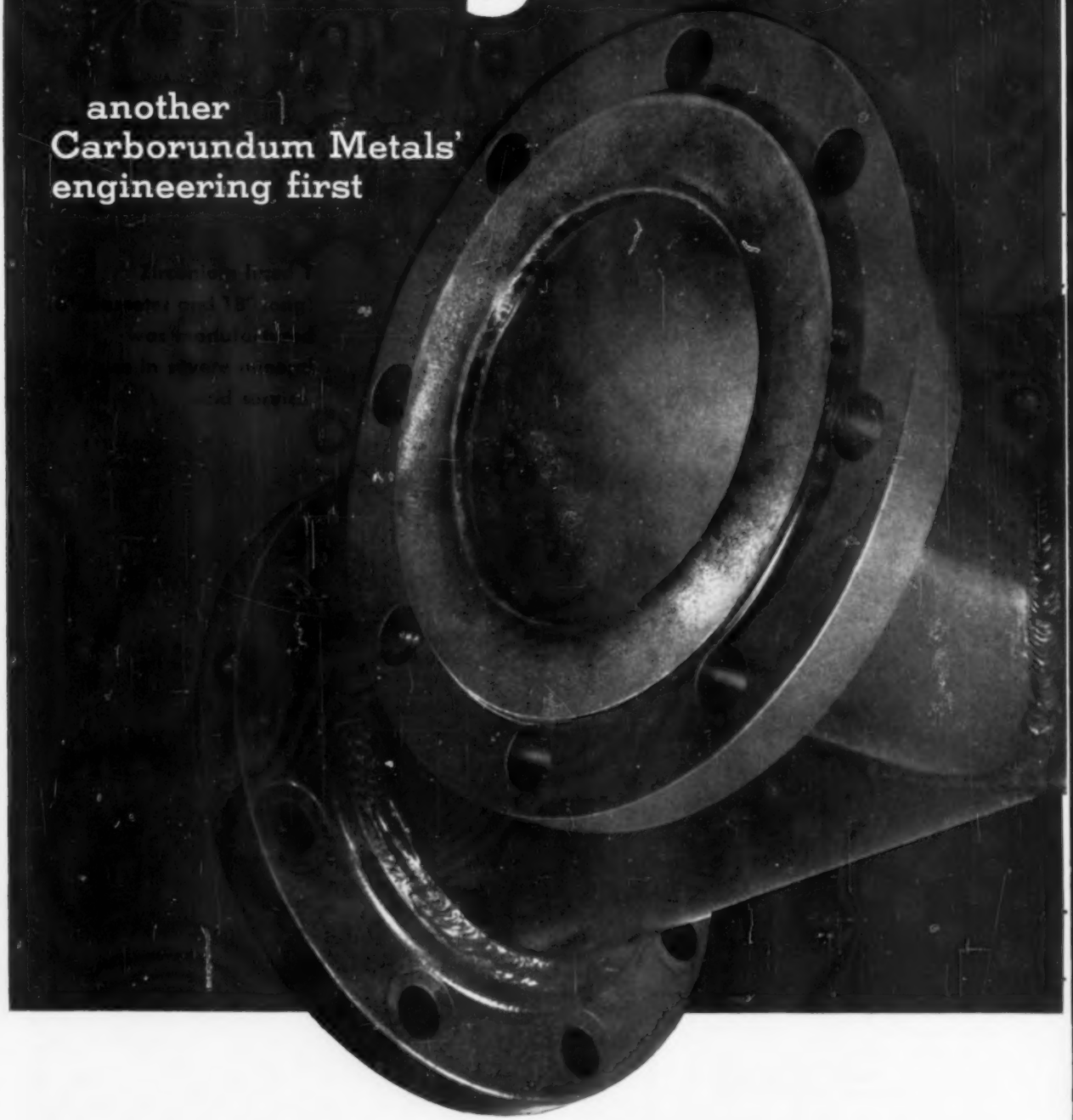
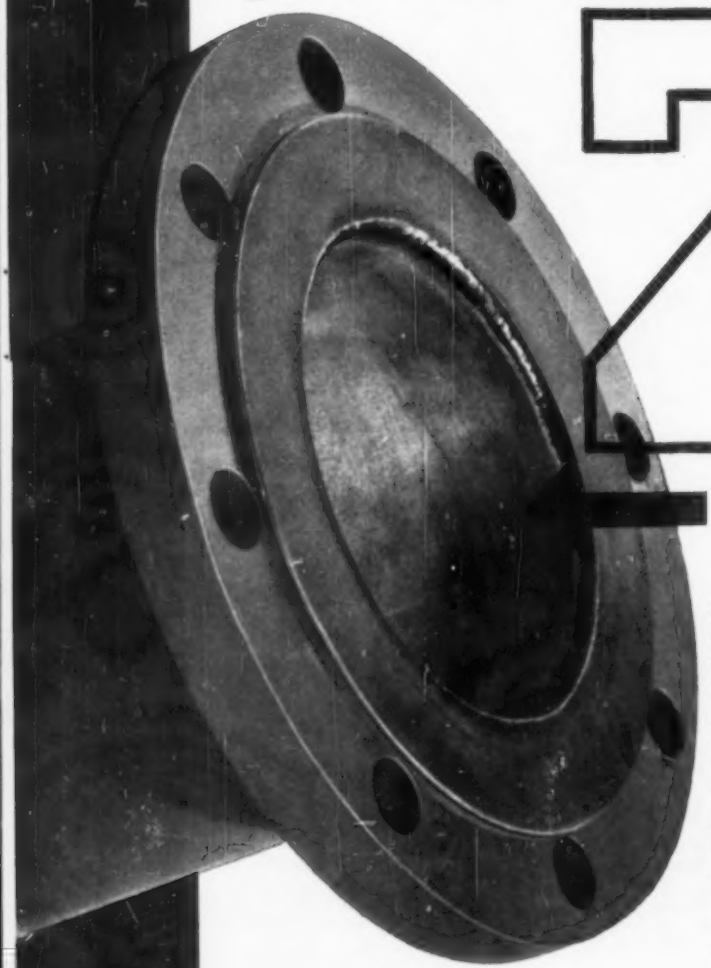


fights corrosion with economy



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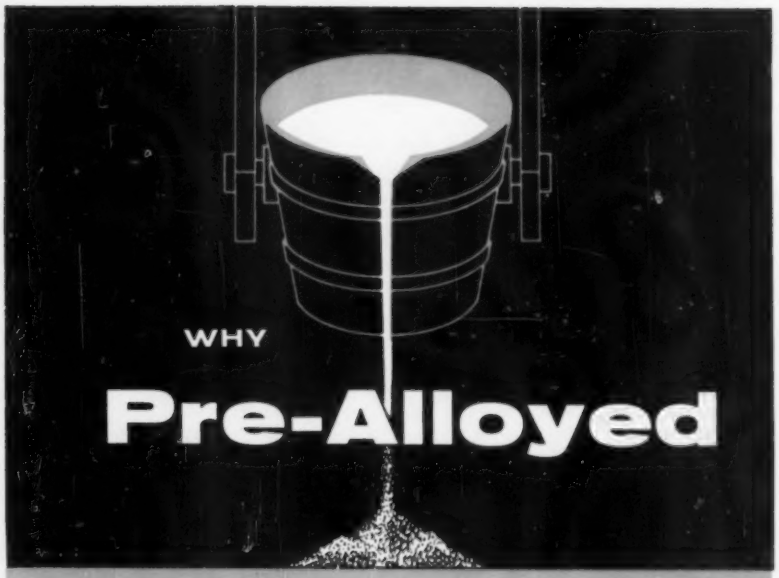

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3 **availability**

Standard powders are available from stock, including Types 304 and 316 stainless, and Vasco 4630A (AISI 4630) alloy steel. This basic nickel-moly analysis is also produced in other carbon contents from .10 to 1.50%. Many special powders are also available from stock in limited quantities. Prompt deliveries of both standard and experimental powder quantities are made from our Latrobe, Pa. plant. *Send us your inquiries.*

Vanadium-Alloys Steel Company
LATROBE, PENNSYLVANIA

Strain Aging . . .

working and aging on it, is that developed by Cottrell, which is reviewed in the paper. Two additional suggestions are made to supplement this theory. The first is that enough carbon and nitrogen atoms may eventually accumulate at some dislocations to form minute precipitates. When the dislocations are torn away from these areas, the precipitates will give rise to excessive strain hardening. This would account for the loss of ductility found at a late stage of aging.

The second suggestion is that a suitable residual stress pattern with high tensile stresses in the surface layers of the sheet may suppress the formation of the markings. When an external stress is applied to such a sheet, the surface layers will reach the yield point first. They cannot yield, however, because of the constraint imposed by the core which is still deforming elastically. Consequently, at no time can the full cross section of the sheet yield plastically, and this is an essential requirement for the formation of a strain marking.

The present state of the production control is reviewed. Chemical control, that is, of the carbon and nitrogen *in solution*, is the first approach. The amount of carbon in solution can now be kept within satisfactory limit by careful box annealing, but this cannot be done for nitrogen. Adequate reduction of the nitrogen in solution can be achieved only by adding a strong nitride-forming element.

When elements such as aluminum, titanium, zirconium and columbium are used for this purpose, a killed steel results. The final product is then expensive. Aluminum is commonly used, but a problem then arises with the surface quality of the resulting sheet. Some success is being achieved in solving this problem. Treatment with vanadium and boron does not result in a killed steel, but the controlled addition of both elements presents problems.

The second approach is in the control of the distribution of residual stresses. Detailed examination of the mechanical factors which give rise to suitable stress distributions has begun. Roll size, roll roughness and sheet grain size are important.

L. E. SAMUELS

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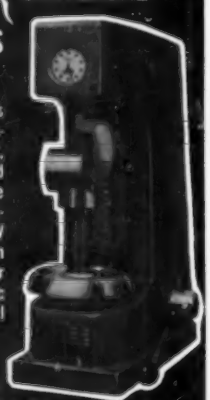
The Buyers Guide For Metals Engineers

Frank UNIVERSAL HARDNESS TESTER



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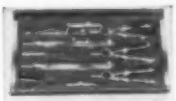

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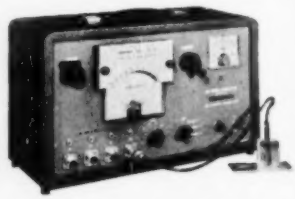

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NEW RIGHT-ANGLE PROBE model "RP" enables measurements in holes down to ½" I.D.

STANDARD PROBE model "SP" enables measurements on convex surfaces down to ⅛" radius of curvature and on concave surfaces down to 2" radius of curvature

MODIFIED STANDARD PROBE model "MP" enables measurements on concave surfaces down to ¼" radius of curvature

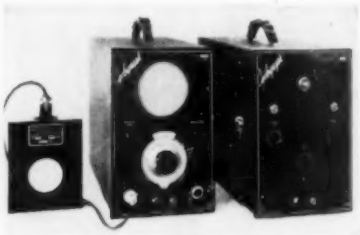
Each of the above probe types is available in 4 different thickness ranges—A, B, C and D, from thick to thin deposits.

Write for latest bulletins and questionnaire to help solve your thickness testing problems

UNIT PROCESS ASSEMBLIES, INC.

LIST NO. 139 ON INFO-COUPON PAGE 171

DICE does it better!



THE CYCLOGRAPH, (Model C)

. . . for unscrambling metal mixups

This instrument permits truly high speed, non-destructive sorting of raw, semi-finished or finished parts by their metallurgical characteristics. With the new Automatic Sorter Unit, speeds up to 300 pieces per minute are possible with the use of suitable feeding equipment. Used by leading industrial firms everywhere.

J. W. DICE CO.

"Non-destructive Testing and Measuring Instruments"

Englewood 3 New Jersey

In Canada: Non-Destructive Testing Corp., Ltd., Toronto

LIST NO. 50 ON INFO-COUPON PAGE 171

Metallizing Wires

Rigidly Specified for Metal Spraying

Spra-Rod

Corporation

2795 East 83rd St., Cleveland 4, Ohio

LIST NO. 189 ON INFO-COUPON PAGE 171

TENSILKUT

Tensile and fatigue test specimens can be accurately machined from foil metals as light as .0005" or heavy .500" plate in less than two minutes. Machined edges are completely free of cold working and the specimen configurations are duplicated within ± .0005".

TensilkuT machines a wide range of metals including steel, aluminium, stainless steel, copper, titanium, uranium, lead, the super alloys and all plastic materials.

Tensilkut table and floor models are available with motors from ½ to 2½ HP. Write for our latest brochure.

Trade Mark Registered U.S. Patent Office Patents Pending United States & Canada.

SIEBURG INDUSTRIES

INCORPORATED

HORSE RANCH ROAD STERLING, CONN.

LIST NO. 131 ON INFO-COUPON PAGE 171

HARDNESS TESTING SHORE SCLEROSCOPE

Pioneer American Standard Since 1907

Available in Model C-2 (illustrated), or Model D, dial indicating with equivalent Brinell & Rockwell C Hardness Numbers. May be used freehand or mounted on bench clamp.

OVER 40,000 IN USE

SHORE INSTRUMENT & MFG. CO., INC.
90-35M Van Wyck Exp., Jamaica 35, N.Y.

LIST NO. 133 ON INFO-COUPON PAGE 171

Inspect
NON-FERROUS–NON-MAGNETIC
Metals . . .

with Magnetic Analysis MULTI-FREQUENCY EQUIPMENT. An eddy current tester with six inspection methods operating simultaneously — for high-speed, non-destructive testing of non-ferrous and non-magnetic tubing, bars and wire from ⅛" to 3" diameter. Detects both surface and sub-surface flaws, and variations in chemical, physical and metallurgical properties at speeds of 200 to 600 ft./min.

"THE TEST TELLS"

For Details Write:

MAGNETIC ANALYSIS CORP.
42-44 Twelfth St., Long Island City 1, N. Y.

LIST NO. 193 ON INFO-COUPON PAGE 171

ULTRASONIC

Thickness Testing from One Side

Rapid, Accurate, Non-Destructive

VIDIGAGE®

14" or 21" Cathode-Ray Screen with direct-reading scales between 0.005" and 2.5"; accuracy 0.1% to 1.0%.

AUDIGAGE®

Portable Thickness Testers for ranges from 0.020" to 4" or 0.060" to 12" of steel; accuracy up to 1.0%.

Detect Laminar Flaws and Lack of Bond

BRANSON INSTRUMENTS, INC.

6 Brown House Rd., Stamford, Connecticut

Specializing in Ultrasonics Since 1946

LIST NO. 81 ON INFO-COUPON PAGE 171

make hardness tests ANYWHERE WITH THE **NEWAGE TESTER**

- CLAMPS, JAWS & BASE PLATE ARE ELIMINATED
- NO CONVERSIONS OR CALCULATIONS
- TEST ANY SIZE, SHAPE OR TYPE METAL
- NO SKILL REQUIRED
- SCALE READINGS IN ROCKWELL & BRINELL
- ACCURACY GUARANTEED

Many thousands used by industry and government. Write, wire or call for additional details and prices.

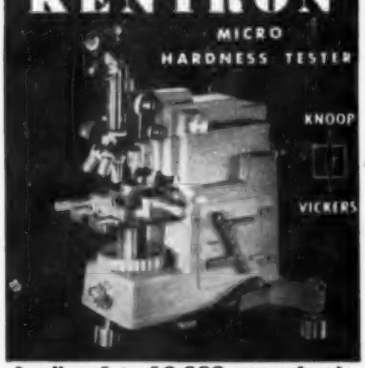
NEWAGE INDUSTRIES, INC.

222 York Road, Jenkintown, Pennsylvania
TUrner 4-8894 Dept. MP

LIST NO. 163 ON INFO-COUPON PAGE 171

KENTRON

MICRO HARDNESS TESTER



Applies 1 to 10,000 gram loads

Write for Bulletin

Kent Cliff Laboratories Div.

The Torsion Balance Company

CLIFTON NEW JERSEY

LIST NO. 53 ON INFO-COUPON PAGE 171

NEW pocket-size THICKNESS GAUGE

For flat or curved surfaces

only **$75.00**

F.O.B. Cleveland

Measures Nonmagnetic Coatings with ±5% ±.0001" accuracy

ELCOMETER measures thickness of porcelain enamel, paints, platings, foils, glass, paper, plastics, and other nonmagnetic coatings quickly and accurately. Gauges flat or curved surfaces and hard-to-get-at spots easily. Needle locking device assures correct reading every time. Complete with leather case containing inner pocket for test strips. Weighs only 6 oz. Completely self-contained.

WRITE FOR ILLUSTRATED FOLDER

FERRO CORPORATION

4155 East 56th Street
Cleveland 5, Ohio

LIST NO. 148 ON INFO-COUPON PAGE 171

Solve

Inspection Sorting Demagnetizing *Problems*

with

MAGNETIC ANALYSIS

MULTI-METHOD EQUIPMENT

Electronic equipment for non-destructive production inspection of steel bars, wire rod, and tubing. Detects mechanical faults and variations in composition and physical properties. Average inspection speed — 120 ft. per minute.

SPECIAL EQUIPMENT

Electronic equipment for non-destructive production inspection of non-ferrous bars and tubing . . . as well as both non-magnetic stainless and high temperature steel bars and tubing — seamless or welded. Mechanical faults, variations in composition and physical properties are detected simultaneously. Average inspection speed — 200 ft. per minute.

WIRE ROPE EQUIPMENT

Electronic equipment for inspecting ferromagnetic wire ropes from 1/32" to 3" diameter. Detects broken, cross-over or missing wires, plus defective welds and deformations at production speeds up to several hundred feet per minute.

COMPARATORS AND METAL TESTERS

Electronic instruments for production sorting of both ferrous and non-ferrous materials and parts for variation in composition, structure and thickness of sheet and plating.

DEMAGNETIZERS

Electrical equipment for rapid and efficient demagnetizing of steel bars and tubing. When used with Magnetic Analysis Multi-Method Equipment, inspection and demagnetizing can be done in a single operation.

MAGNETISM DETECTORS

Inexpensive pocket meters for indicating residual magnetism in ferrous materials and parts.

"THE TEST TELLS"

For Details Write:

MAGNETIC ANALYSIS CORP.

42-44 Twelfth St., Long Island City 1, N. Y.

LIST NO. 51 ON INFO-COUPON PAGE 171

GOOD USED EQUIPMENT AT REAL SAVINGS TO YOU!

2—Like-new roller hearth furnaces! Surface Combustion recirculating ovens for tempering or aluminum treating. Inside work dimensions: 49 in. wide x 17½ ft. long x 26 in. high.

Gas-fired for 1200° F. Complete with automatic doors and fast discharge mechanism, two recirculating fans with 15 hp. (220/440/3) motors, turbocompressor, safety equipment, and Brown Electronik strip chart recorders.

1—Same as above except 45 ft. long. Bricklined.

METAL TREATING EQUIPMENT EXCHANGE, INC.
9825 GREELEY ROAD
DETROIT 11, MICHIGAN

LIST NO. 142 ON INFO-COUPON PAGE 171

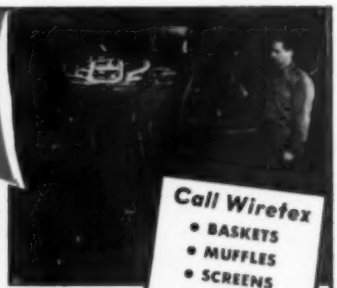
JELLIFF HEAT-TREATING BASKETS

All shapes, sizes, alloys.
Estimates without obligation.

THE C. O. JELLIFF MANUFACTURING CORP.
SOUTHPORT, CONNECTICUT

LIST NO. 91 ON INFO-COUPON PAGE 171

WIRETEX Pit Furnace ASSEMBLY



cuts treating time 50%
lowers labor costs 66%

A well known foundry customer* substituted **WIRETEX** Inconel baskets and frames for cast iron pots and carriers for their pit type heat treating furnaces and discovered a way to save hundreds of dollars in labor, materials, maintenance and replacements. Best of all . . . production skyrocketed!

WIRETEX engineered baskets can do the same for you—it'll pay to investigate!

Specialists in processing carriers since 1932

Wiretex 5 Mason St., Bridgeport 5, Conn.

Call Wiretex
- BASKETS
- MUFFLES
- SCREENS
- RETORTS
- TRAYS
- FIXTURES

to resist acids, heat, abrasion or exposure. Small, large — standard or custom made in every weave, metal and alloy.

*Actual case history story, photos and WIRETEX catalog, free for asking. Write today!

LIST NO. 114 ON INFO-COUPON PAGE 171

Martin P. Tregnan
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Blair Engineering Co.
4100 Grape St.
Denver 16, Colo.

Richard D. Lindner
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Wethersfield, Conn.

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Rockford, Illinois

William McAtee
626 N. DeQuincy St.
Indianapolis 1, Indiana

Harry I. Dixon
Metallurgical Products Co.
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Brookline 46, Mass.

Carl H. Schmidt Co.
16405 W. 8 Mile Rd.
Detroit 35, Mich.

A. A. Gustafson
161 Griggs—Midway Bldg.
Fairview at University
St. Paul 4, Minnesota

J. Kelvin Stahl
716 River Road
Trenton 8, New Jersey

There's a STANWOOD Heat Treating Equipment Sales Engineer as near as your phone!

R. Brock Steele
254 West 31st Street
New York 1, New York

J. N. Stewart Co., Inc.
532 University Bldg.
Syracuse 2, N.Y.

Charles Plant Jr. and Warren S. Lum
Alloy Sales & Service
8905 Lake Avenue
Cleveland 2, Ohio

Joseph S. Abel
5213 Celia Place
Pittsburgh 24, Pa.

Eugene S. Craig
Craig Indust. Equipt. Co.
1101 Poplar Avenue
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M. K. Griggs Co., Inc.
322 West Jefferson
Dallas, Texas

M. K. Griggs Co., Inc.
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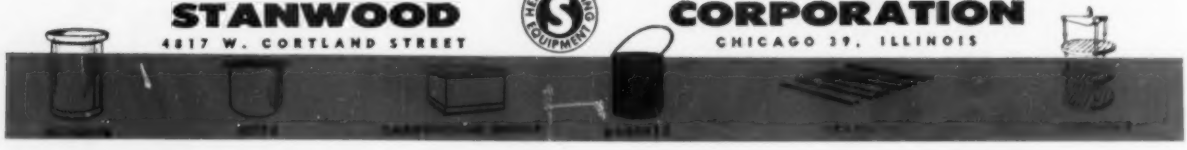
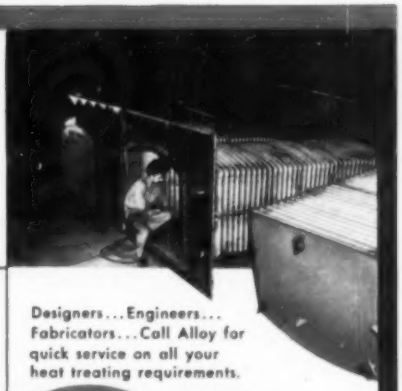
STANWOOD CORPORATION
4817 W. CORTLAND STREET — CHICAGO 39, ILLINOIS

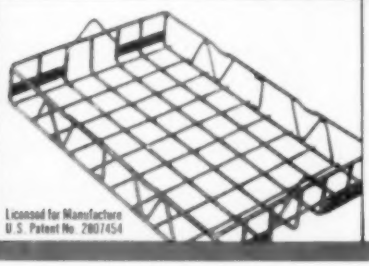


LIST NO. 12 ON INFO-COUPON PAGE 171

ALLOY ENGINEERED
RETORTS & BASKETS

Engineering answers and highest quality manufacturing . . . developed by years of alloy specialization.





Licensed for Manufacture U.S. Patent No. 2807454

Designers . . . Engineers . . . Fabricators . . . Call Alloy for quick service on all your heat treating requirements.

ALLOY ENGINEERING CO.

74 SHELDON ROAD
BEREA, OHIO

LIST NO. 184 ON INFO-COUPON PAGE 171

PRODUCED AND PRICED RIGHT FOR YOUR ELECTRIC FURNACE NEEDS

DYNA-TROL

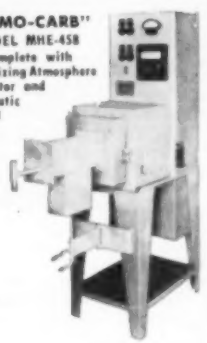
MODEL NO.	FIRING CHAMBER (H.W.D.)	PRICE (300° to 2000°)	PRICE (400° to 2300°)
P46	4½"x4½"x8"	$90.00	$110.00
P79	6"x6"x9"	$205.00	$225.00
P918	9"x9"x18"	$480.00	$528.00
P414	14"x14"x14"	$525.00	$603.25
P124	12"x12"x24"	$715.00	$822.25
P818	18"x18"x18"	$775.00	$887.50
P136	18"x18"x36"	$1125.00	$1312.50

Automatic Controls Available on all Models

Model P-79

- Infinite zone temperature control
- Zone temperature indication by Pyrometer Selector Switch
- Automatic hold and cut-off instrument available
- Patented element holders
- Infinite variety of time-temperature curves obtainable
- Rugged construction

"ATMO-CARB" MODEL MHE-458
Complete with Carburizing Atmosphere Generator and Automatic Control



$1325.00
Other Sizes and Arrangements Available

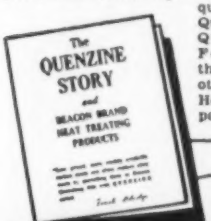
L&L MANUFACTURING CO.
Chester 77, Pa.

LIST NO. 138 ON INFO-COUPON PAGE 171

FREE

***the* QUENZINE STORY**

Low priced, more readily available carbon steels can often replace alloy steels when quenched in Beacon Quenching Oils with QUENZINE added. For information on this new additive and other Beacon Brand Heat Treating Compounds write to . . .



KELCO

ALDRIDGE INDUSTRIAL OILS, Inc.
3401 W. 140th St., Cleveland 11, Ohio

LIST NO. 29 ON INFO-COUPON PAGE 171

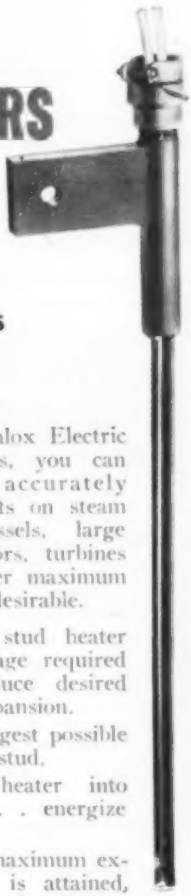
END POT FAILURE

Switch to *scheduled* pot maintenance with low-cost pressed-steel pots for lead, salt, cyanide, oil-tempering, metal-melting. Can't turn suddenly defective, because no faulty steel survives drawing. Request catalog from Eclipse Fuel Engineering Co., 1127 Buchanan St., Rockford, Ill.

Eclipse INDUSTRIAL COMBUSTION DIVISION

LIST NO. 176 ON INFO-COUPON PAGE 171

NEW CHROMALOX STUD HEATERS



for shrink-tightening large studs and bolts

With Chromalox Electric Stud Heaters, you can easily and accurately shrink-fit bolts on steam pressure vessels, large presses, motors, turbines . . . wherever maximum tightness is desirable.

1. Choose stud heater of wattage required to produce desired stud expansion.
2. Drill largest possible hole in stud.
3. Insert heater into hole . . . energize heater.
4. When maximum expansion is attained, draw down bolt.
5. De-energize and remove heaters. Cooling and contraction draws down to desired tightness.

FREE! Send for new Bulletin L-1244. Contains detailed product description, illustrations of how to use, and table of Chromalox Stud Heater sizes, ratings and prices.

2626

CHROMALOX Electric Heat
INDUSTRIAL · COMMERCIAL · RESIDENTIAL
EDWIN L. WIEGAND COMPANY
7755 THOMAS BLVD., PITTSBURGH 8, PA.

LIST NO. 191 ON INFO-COUPON PAGE 171

HEIL CORROSION PROOF EQUIPMENT

TANKS Pickling, Plating, Anodizing, Storage. Sheet Linings, Coatings, Steel and Alloy Construction.

ACID HEATING Nocordal (Impervious Graphite), Lead and Alloy Heat Exchange Units. Immersion and External Types.

VENTILATING EQUIPMENT Hoods, Fans, Ducts, Stacks, Scrubbers for Collecting and Removing Corrosive Fumes. Solid Plastic Lined Steel.

STEAM JET AGITATORS For Heating and Agitating Acid Solutions. Special Lead Alloy and Solid Impervious Graphite.

Also Baskets—Crates—Hairpin Hooks

Write for fully descriptive Bulletins

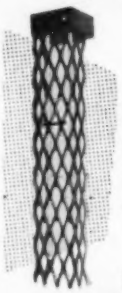
CHEMICAL-PROOF LININGS · TANKS HEATERS PLASTICS

HEIL PROCESS EQUIPMENT CORPORATION

12901 ELMWOOD AVENUE • CLEVELAND 11, OHIO

LIST NO. 187 ON INFO-COUPON PAGE 171

there's a *Glo*-QUARTZ* IMMERSION HEATER for Your Every Heating Requirement



- INSTANT HEATING
- SHOCK-PROOF
- AVAILABLE IN ALL VOLTAGES —WATTAGES, ONE AND THREE PHASE

Available from your Electroplating Distributor

WRITE FOR BULLETIN ▶

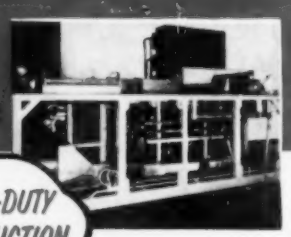
Glo-QUARTZ*

ELECTRIC HEATER CO., INC., Willoughby, Ohio

*Reg. U.S. Pat. Off. Phone: Willoughby 2-5321

LIST NO. 148 ON INFO-COUPON PAGE 171

EVERY PITTSBURGH INDUCTION HEATING FURNACE installation is backed by these outstanding features:



- Pre-testing of Unit
- One-Year Warranty
- Maximum Safety
- Labor and Space Savings
- Greater Margin of Profit

HEAVY-DUTY CONSTRUCTION

Consult a PIH Engineer for complete information on a wide range of applications for optimum heating of all metals for numerous metal working operations such as forging, rolling, annealing, extrusion, and others.

Write for detailed brochure with frequency chart

PIH

PITTSBURGH INDUCTION HEATING COMPANY INCORPORATED

615 Washington Road, Pittsburgh 28, Pa. Phone LO. 3-6020

LIST NO. 181 ON INFO-COUPON PAGE 171

COMING IN JANUARY

TO MEET THE NEEDS OF METALS ENGINEERS AROUND THE WORLD

THE "INTERNATIONAL" ISSUE OF METAL PROGRESS

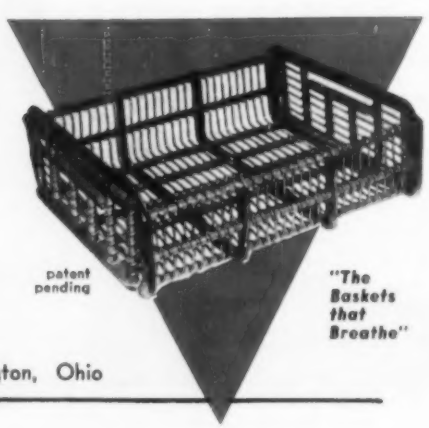
AN ENGINEERING FIRST IN BASKET FABRICATION

bixco HEAT TREAT BASKETS

These Job-Tested and Proved Designs Incorporate:

- SPECIAL LOOPED WIRE
- NON-WELDED SUPPORT RODS
- NON-WELDED FRAMING
- FLOATING INNER FRAMES

First and Only Baskets with All These Features



patent pending

"The Baskets that Breathe"

WRITE for NEW 1959 CATALOG with BIX COMPANY'S COMPLETE LINE of BASKETS and FIXTURES

bix **COMPANY** Fairgrounds Rd., Wellington, Ohio

LIST NO. 185 ON INFO-COUPON PAGE 171

SURPLUS FURNACES FOR SALE

ATMOSPHERE GENERATORS

250 to 15,000 CFH Exo and Endo

BOX TYPE

24x36x18	Lindberg	50KW	2000°F
48x84x24	American	100KW	1850°F
24x36x14	Surface	Gas	1850°F
54x96x24	Surface	Gas	1850°F

PIT TYPE

20x22	G.E.	48KW	1200°F
48x60	Lindberg	90KW	1250°F
48x96	Surface	Gas	1250°F
48x96	Lee Wilson	Rad. Tube	1850°F

CONVEYOR TYPE RECIRCULATING

72x40'x30	Surface	RlrHrth Gas	1250°F
27x15'x12	R&S	MshBlt Gas	1250°F

BOX TYPE RECIRCULATING

8'x12'x42"	Lindberg	Gas	1250°F
66"x16'x76"	Lindberg	180KW	1250°F
60"x10'x42"	Lindberg	180KW	1250°F
42"x16'x30"	Lindberg	120KW	1250°F

BOX & CONVEYOR OVENS

6'x30'x18"	Mich Oven Conv	150KW	550°F
6'x30'x18"	Mich Oven Conv	150KW	400°F
5'x16'x12"	Mich Oven Conv	150KW	800°F
2'x2'x4'	Rockwell Box	5KW	550°F
7'x7'x7'	Young Bros Box	Gas	650°F
19"x19"x19"	Despatch Box	5KW	850°F

BRAZING TYPE

18"x42"x12"	Lindberg Pshr	60KW	2500°F
18"x42"x10"	Westinghouse Pshr	50KW	2050°F
62"x18'x24"	GE RlrHrth	655KW	1650°F

SEND FOR COMPLETE LIST

THE JOE MARTIN CO., INC.

19256 John R. St. TWinbrook 2-5500 Detroit 3, Mich.

WANTED

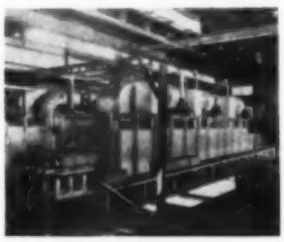
SIR PLUS FURNACES

REWARD

WE PAY CASH FOR SURPLUS INDUSTRIAL FURNACES AND RELATED APPARATUS

LIST NO. 160 ON INFO-COUPON PAGE 171

PACIFIC FURNACES ARE ENGINEERED FROM THE INSIDE OUT



Pictured is a Pacific Air Draw Furnace currently drawing and tempering 3000 lb. of pearlitic malleable iron castings per hour at a leading foundry. This Pacific engineered furnace features hydraulic pushers, three-zone automatic cycling, and automatic unloading at the completion of the operation. It operates at 1400° F.

Pacific ENGINEERS . . . . BUILDS . . . . SERVICES all types of industrial heating equipment.

FOR COMPLETE INFORMATION ON OUR SERVICES —WRITE OR CALL

THE Pacific INDUSTRIAL FURNACE CO.

24680 Telegraph Road, Detroit 41, Michigan
Phone: Kenwood 7-4250

LIST NO. 173 ON INFO-COUPON PAGE 171

POT-TYPE SALT BATH FURNACE

The features listed below are but a few of the in-built advantages of the **LUCIFER 2055 SERIES.**

- Eliminates atmospheric problems (oxidation, scaling and decarburization)
- Rapid constant heat
- Choice of 10 models
- Heat ranges to 1,700° F.
- All controls included (automatic indicating controller, selector switch with two thermocouples)
- Quick easy installation
- Low initial cost . . . low upkeep
- Top production performance with unskilled labor
- Minimum replacement down-time

Lucifer Furnaces, Inc., manufactures many standard electric heat treating furnaces and maintains a design department to create special units. For engineering assistance, parts or product information write or call . . .

LUCIFER FURNACES, INC.
Neshaminy 7, Pennsylvania
Diamond 3-0411

BY LUCIFER FURNACES

LIST NO. 122 ON INFO-COUPON PAGE 171

don't hide it under a BUSHEL...

. . . if you have an idea in which you figure an aluminum extrusion will best solve a manufacturing problem involving a functional metal parts application. G.E.I.'s highly skilled engineering staff is eager and ready to discuss your idea with you, at no obligation, on one part or a million, to determine if your theory can be put to practical use. G.E.I.'s engineers specialize in adapting extruded aluminum to new functional roles—helping customers make extruded aluminum save time and money. G.E.I. is equipped to handle all aluminum processing services, including extruding, fabrication, anodizing, machining, etc.

GENERAL EXTRUSIONS, INC.

4040 Lake Park Road STerling 8-0681
YOUNGSTOWN, OHIO

Missouri, S. Illinois Representative:
Frank May Co., 4378 Lindell Blvd., St. Louis 8, Mo.
Michigan Representative:
Howard B. Jones, 15842 Kentfield Ave., Detroit 23, Mich.
Southern Representative:
Jack Widman, 1382 Poplar Ave., Memphis, Tenn.
W. C. Jones Distributing Co., 4450 Kuyter Rd.
Cincinnati, (Rossmoyne) Ohio

LIST NO. 141 ON INFO-COUPON PAGE 171

AMMONIA DISSOCIATORS

Drever 3000 CFH Units

60 KW, 3-phase, each with Brown 1500-33PS-21 and 105-C4PS-13, plus transformers and contactor. Weight, 3000 lb. Operating temperature, 1750° F. Practically new.

Also other used units such as:

- ★ Nitriding, Tempering
- ★ Rotary Carburizing Units
- ★ Salt Bath Units
- ★ plus other items

The W. H. Kay Co.

4040 Mayfield Rd. Cleveland 21, Ohio
Phone, EVergreen 1-3440

LIST NO. 188 ON INFO-COUPON PAGE 171

Sel-Rex®

PRECIOUS METALS FOR INDUSTRIAL PLATING

BRIGHT GOLD
Mirror-bright finish in any thickness directly from the bath. Patented

PUR-A-SALTS
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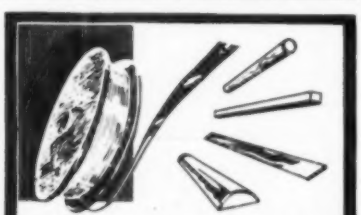

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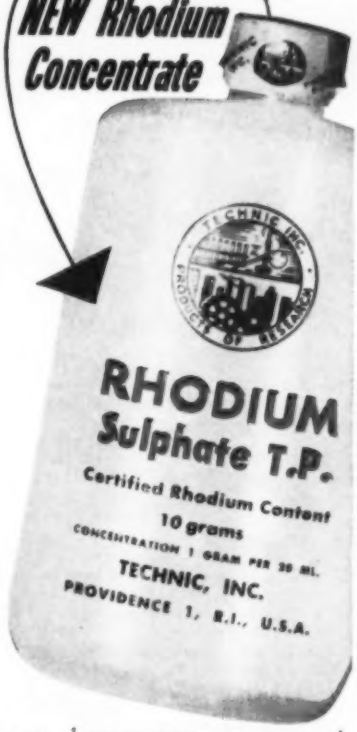

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Stello Products Company, Logansport, Indiana, manufacturer of tags, license and "booster" plates, had the problem of excessive direct labor charges. In the previous expensive method of making these items, plates had to be stamped from bare metal —and then cleaned individually—and spray painted on both sides. This method did not give the uniform quality demanded—and Stello turned to Roll Coater for a solution.

SOLUTION:

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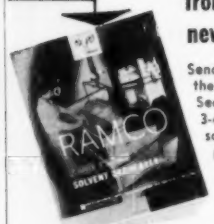

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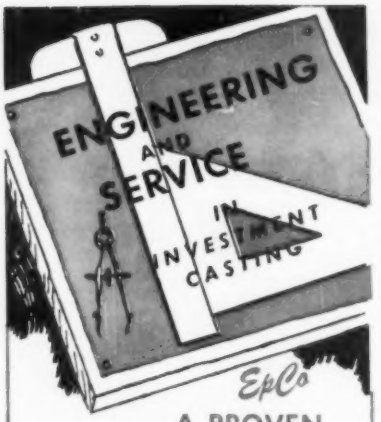

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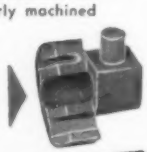

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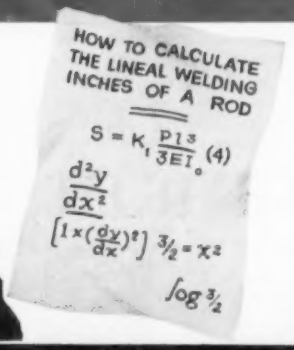
HOW TO CALCULATE THE LINEAL WELDING INCHES OF A ROD
$S = K_1 \frac{P l^3}{3EI_o}$ (4)
$\frac{d^2y}{dx^2}$
$\left[1 \times \left(\frac{dy}{dx}\right)^2\right]^{3/2} = x^2$
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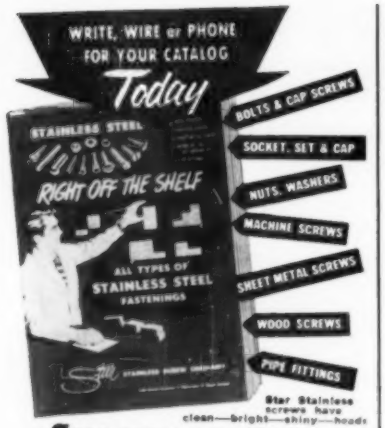

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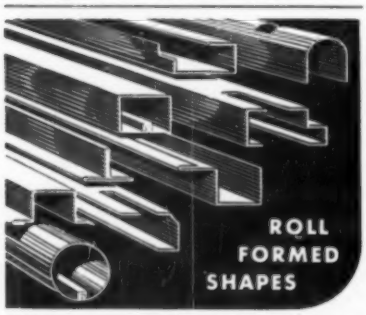

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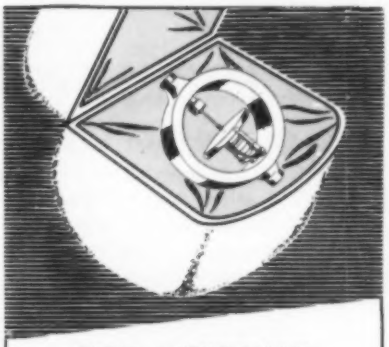

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Metallurgy in the Space Age

Digest of several talks presented at the S.A.E. National Aeronautical Meeting in Los Angeles, Sept. 29 through Oct. 4, 1958.

THE SPACE AGE challenge to the metallurgist was evident during the National Aeronautical Meeting of the Society of Automotive Engineers, Inc., held in Los Angeles during the week of Sept. 29. Constantly rising aircraft and missile speeds continually make better materials necessary. Air friction at the supersonic speeds now common results in heat problems never encountered before. No longer are the light metals satisfactory.

Aluminum and magnesium alloys cannot withstand aerodynamic heating of bodies undergoing supersonic flight within the earth's atmosphere. Other materials possessing higher moduli, greater strength and thermal stability are needed. Higher densities of most of these materials pose major design problems because strength-weight ratios are of greater importance than ever before. Furthermore, it looks as if from 40 to 80% of flight structures will require such materials.

The metallurgist is asked to provide newer materials with closer tolerances and thinner gages. Sheet materials are needed in widths from 48 to 120 in., with lengths from 240 to 360 in., and thicknesses ranging from 0.005 to 0.110 in. Tolerances are asked to be one half the present A.I.S.I. standards to permit optimum weight savings and improve fabrication procedures.

Honeycomb structures require materials from 0.001 to 0.005 in. thick and to plus tolerances not exceeding 0.0005 in. Furthermore, all processing techniques require metallurgical counsel and guidance. Continued development of brazing alloys is a *must*.

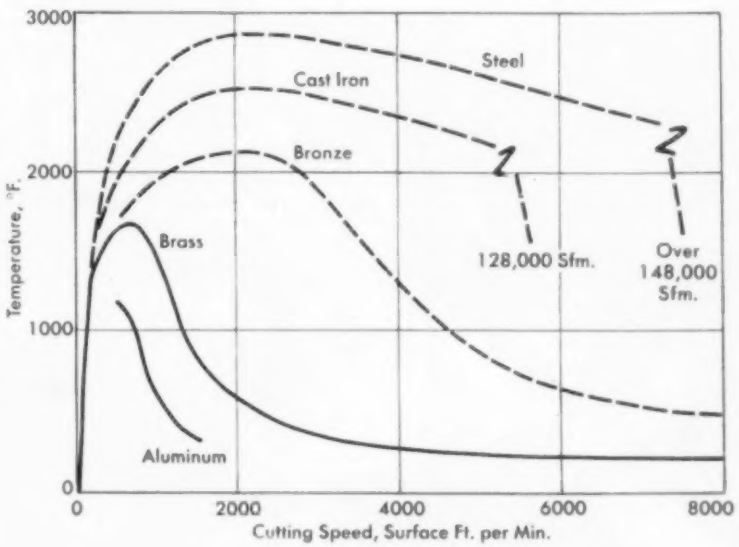
Forming

Many materials possessing desirable strength-weight advantages at elevated temperature are difficult to form at room and even slightly elevated temperatures. As an example, A. P. Binsacca, Northrop Div., Northrop Aircraft, Inc., mentioned that HK 31 magnesium alloy in the H 24 strain hardened temper required hot working at 650° F. for extensive forming and close dimensional tolerances. Speaking of the titanium alloys, he stated, "The alpha types possess good strength, stable toughness and are weldable but difficult to form. The older beta types provide best strength and formability, but not long-time high-temperature stability. The alpha-beta types provide good strength stability and formability. The new beta alloy B 120 VCA forms readily and needs only to be air cooled from solution temperature."

Discussion of this and other papers throughout the sessions suggested that lack of formability of titanium and titanium alloys is not essentially inherent but due to variability in strength, ductility and tear resistance within each sheet and each lot.

Producers have gone a long way in overcoming such deficiencies, but increased homogeneity is still a requirement. Hydrogen pickup in titanium alloys during thermal treatments and in pickling operations is a continuing problem.

The precipitation hardening alloys (17-7 PH, PH 15-7 Mo, AM 350, AM 355 and A-286) in the annealed or solution treated conditions possess forming characteristics comparable to the A.I.S.I. 300 series of austenitic alloys . These materials scale when heated to 1400° F. and higher in normal atmospheres. Since optimum design utilizes minimum sheet thickness, safety factors to account for loss of thickness due to removal of scale are not wanted. Pickling causes size changes and raises susceptibility to intergranular attack. Forming of many simple components is being done at room temperature on such materials as Inconel, Monel, M-252, HS 25, HS 21, L-605 and N-155. Hot forming, if needed, should be done within the solution range.



Graph of Temperature Against Cutting Speed. Note that temperature rises to a peak and then drops. Peak temperature depends on material being machined

Beryllium is being studied for structural applications. Though light and strong, it lacks ductility. Vacuum hot pressed beryllium has provided sheets from 0.020 to 0.060 in. thick, 24 in. and over in width, and 60 in. long. Unidirectional properties appear to be eliminated, and elongations, both longitudinal and transverse, greater than 10% have been obtained. Rolling temperatures ranged from 1300 to 1400° F. Above 1400° F. grain growth and lower ductility occurred. Since beryllium is toxic, processes that

Space Age . . .

generate dust, fumes or vapors must be confined.

Sheet molybdenum has enough ductility at room temperature to permit mild deformation. However, best forming practices require metal at 200 to 1100° F. depending upon severity of deformation.

The aircraft industry is using available tooling and facilities with modifications to process these new materials. Lyle Boarts, North American Aviation, Inc., stated that "titanium alloys and 17-7 PH steel are being formed successfully into such typical shapes as "hat" sections, Z frames, and channels by the trapped rubber process in hydropresses, hydroform equipment and in drop hammers."

Aluminum cover plates have been used on titanium and titanium alloys to aid hydropress forming. The process is being used to form titanium and tianium alloys into shapes such as flange cups, domes, semitubular deep recessed parts, and flat pieces with curved flanges.

Drop hammers now preform complex shapes before hot sizing. Dies are not heated, and several blows can often be struck before parts require reheating. Finish forming is done on hot straightening presses or fixtures.

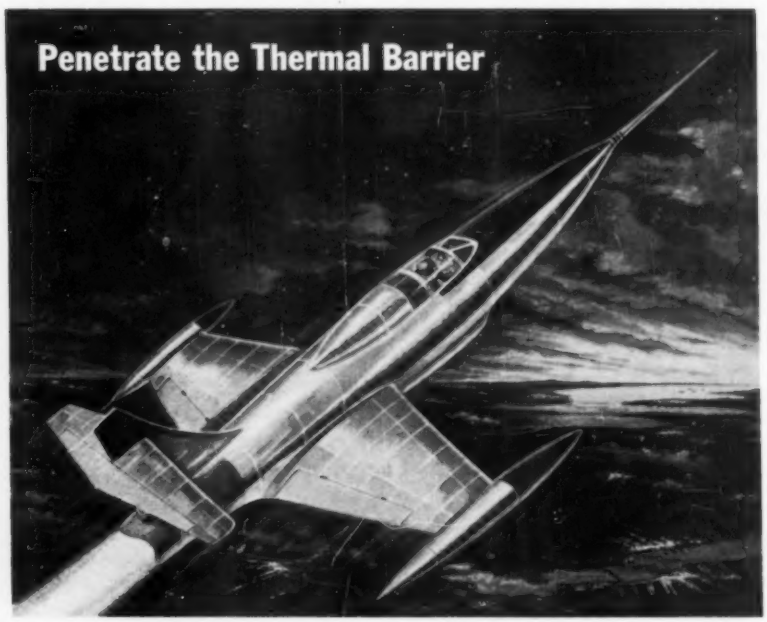
Simple shapes of 17-7 PH often require but one die, while complex ones need starter and finish dies. Simple contoured parts are either partially or fully formed in the annealed condition.

Machining

Speeds ranging to 15,000 sfm. for aluminum and magnesium alloys are not attainable on the higher density and high-strength materials. These are difficult and sometimes nearly impossible to machine by conventional methods. Erosion principles for material removal include electrical discharge, electrolytic and ultrasonic processes. The three processes can be used on electrically conductive material, but the ultrasonic method is the only one applicable to nonconductive materials. They are being applied for drilling, die sinking, forming irregular internal shapes, grinding of tools and surface preparation.

Electrodes are being made from yellow brass, copper-tungsten alloy, silver-tungsten alloy, tungsten carbide, carbone, and Elo-met. The latter is a 50-50 tin-zinc alloy which melts at 640° F. and is cast into desired shapes. It is particularly useful for making electrodes for forming die cavities. Chromium plating extends their life as much as 50:1. Holes and cavities of varying geometric shapes are machined to tolerances of ±0.0005 in. Virtually no heat is generated in the workpiece, and holes 0.005 in. apart can be drilled with no distortion of holes or mutilation of remaining web. Holes as small as 0.002 in. diameter have been drilled through 3/8-in. thick plate.

Electrical discharge grinding is done with a brass wheel rotated at 100 to 200 rpm. to produce matte finishes from 10 to 20 micro-in. Cuts of any width or depth are limited only by wheel size, and are possible in a single pass. Tungsten



MicroMach extra-high-tensile stainless steel sheets

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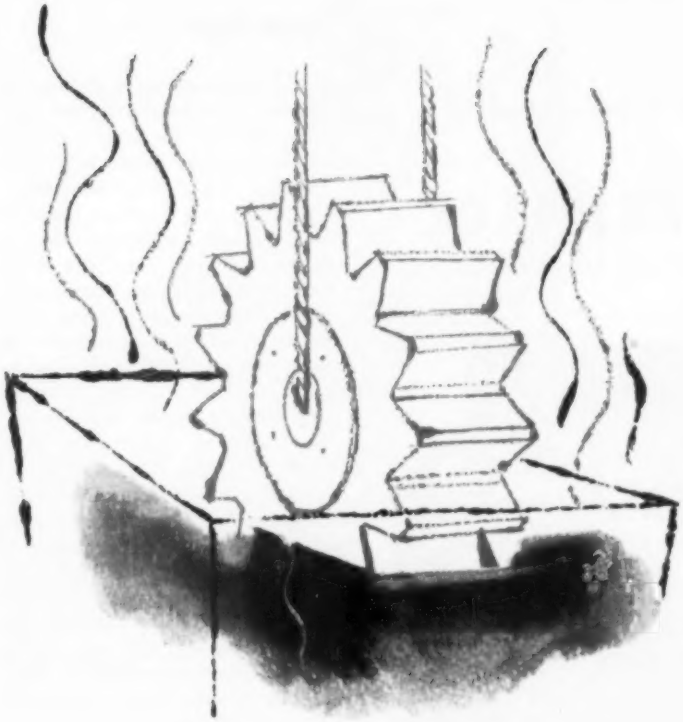

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carbide tools have up to 4½ times the life of conventionally ground ones, and costs may be as low as 35% of those for usual processing.

"Ultra High-Speed Machining", a paper by Ken Sparling, Lockheed Aircraft Corp., presented the data shown in Fig. 1. There is a steady increase in tool temperature with increasing speed up to a given point, beyond which tool temperatures actually decrease with continuing increase of speed.

Preliminary studies have resolved some theories concerning high-speed machining. Limited testing showed that the high speed steels are better than carbide tools. With S.A.E. 4340 workpieces (tested in various conditions from fully annealed to hardened and tempered to Rockwell C-53), tools did not fail up to 150,000 sfm. with depths of cuts varying from 0.002 to 0.030 in. Tools were used repetitively without regrinding, and surface finishes to 15 micro-in. were obtained. Hardness increased from 1 to 4 points Rockwell C to a depth from 0.004 to 0.010 in. The original hardness has little effect on the cutting action or final condition of a tool. Chips as such were nonexistent in the tests made.

Chem-milling is being used in production on practically all materials. Among them are aluminum and magnesium alloys, corrosion and heat resistant alloys (including the A.I.S.I. 300 and 400 series, and the precipitation hardening types), titanium and titanium alloys, nickel and cobalt-base corrosion and heat resistant alloys, toolsteels and refractory metals.

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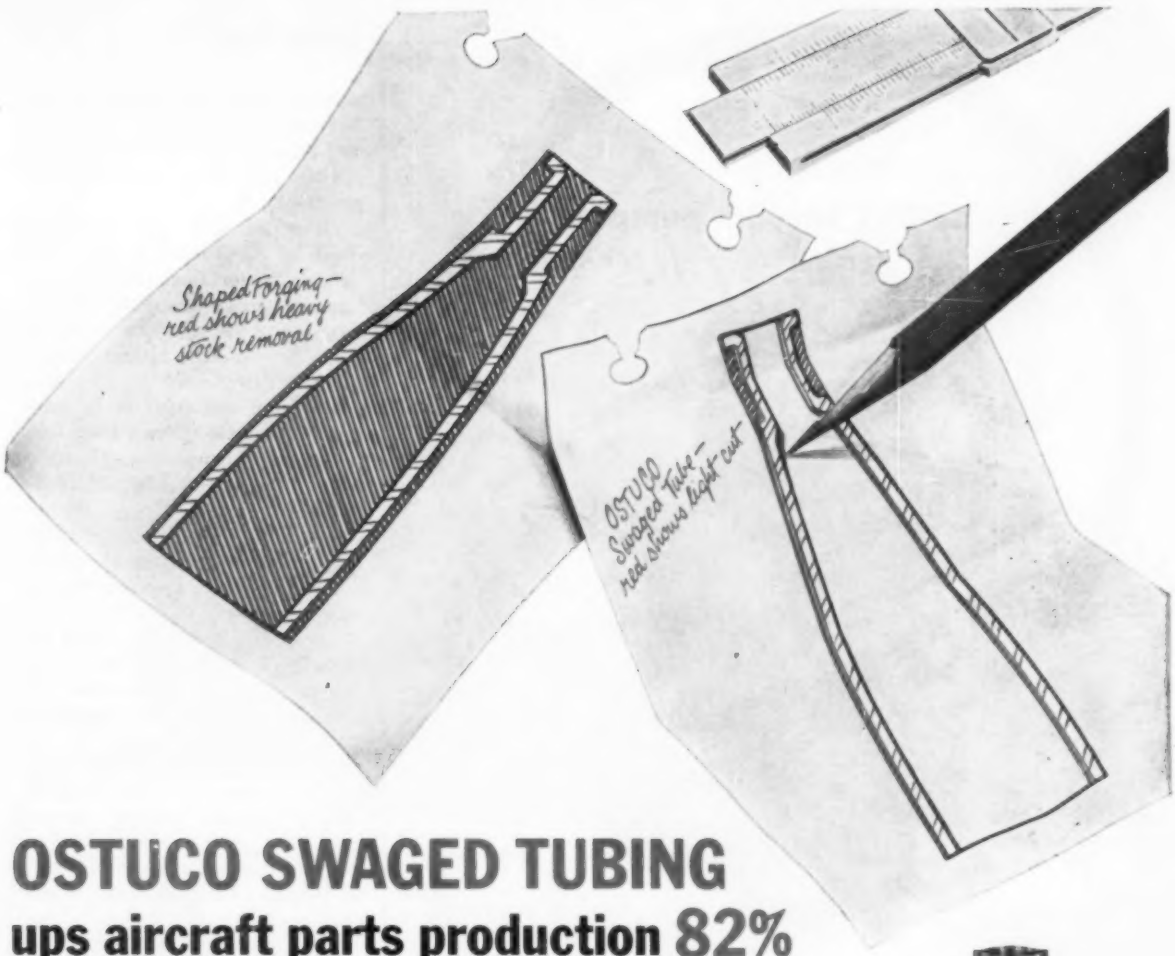

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sides of sheets and components may be treated at the same time, and (*d*) tolerances of ± 0.002-in. metal removal plus actual stock tolerances are obtained.

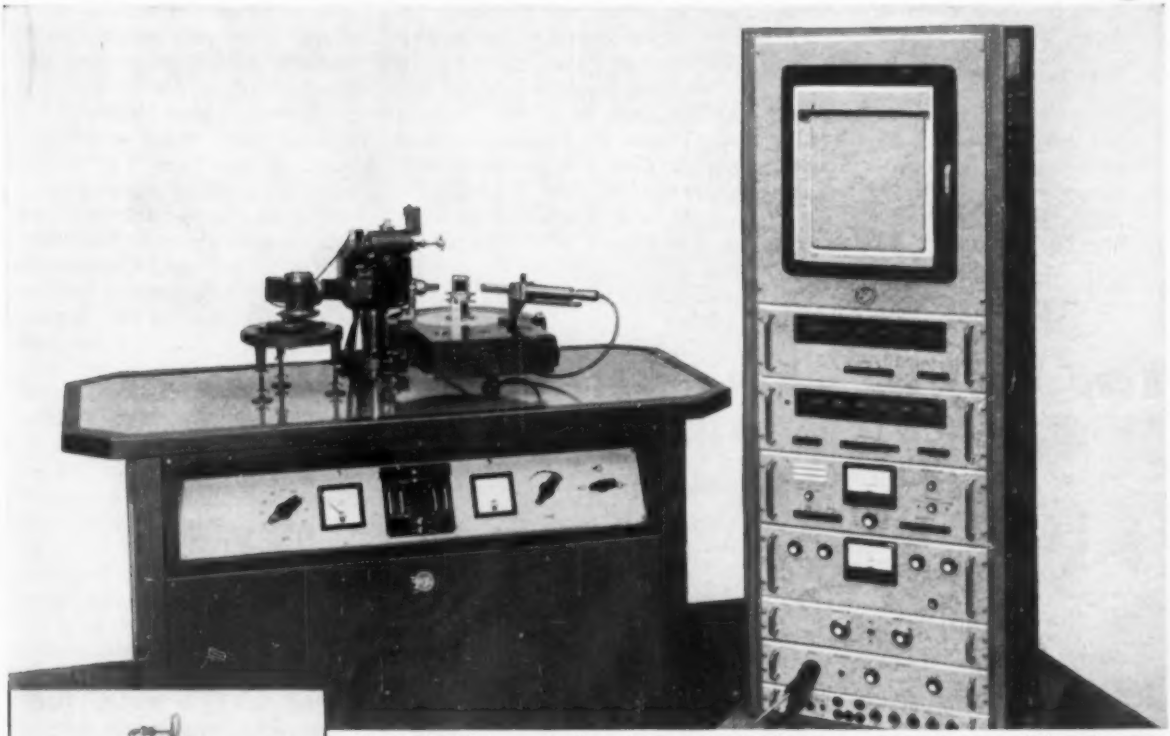
Other features are: Maximum depth of cut is 0.500 in. but when depths greater than 0.125 in. are required, special handling may be necessary; the minimum pattern width is triple the removal depth, solution flow across surfaces must be uniform, and parts to be processed must be clean, free from scale and contaminants. Furthermore, masking material should be relatively impermeable to the etchant, adherent to the part throughout the process, and readily removable when the processing has been completed.

Regarding hydrogen pickup in titanium and titanium alloys, no definite increase has been shown in alpha materials, no significant amount has been found in low beta-phase alloys, but there is measurable increase in the high-beta alloys. These require vacuum degassing after processing. This suggests that hydrogen pickup may be related to the amount of beta phase present.

Metallographic examination of specimens from processed A.I.S.I. 4130 structural steel, 17-7 PH (TH-1075 condition) and Inconel "X" shows no evidences of intergranular attack and no significant effects on the mechanical properties.

Abrasive belt machining was discussed by M. M. Gilman, North American Aviation, Inc. Such processing is being used for the preparation of honeycomb sandwich components before and after brazing, and for "skin sizing." Tolerance limits of 0.005-in. maximum burr height, and maximum clearance between facing sheets and core structure components of 0.004 in. (necessary for good brazing) are being met successfully.

Stainless steels are being belt ground up to 4500 sfm., and feeds of from 18 to 30-ft. per min. AM 350 sheets are being ground at 3000 sfm. with speeds of 18 ft. per min. Metal removal approximates 0.0005 in. per pass. Very thin-gauge AM 350 material is held under tension and refrigerated vacuum plates to dis-



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Heat treatments for 17-7 PH and AM 350 alloys were items discussed by William F. Castell, Lockheed Aircraft Corp. In-process annealing is done at 1900° F. ± 25° for 5 to 10 min. Transformation treatment is done at 1400° F. ± 25° for 90 min. followed by cooling to 60° F. or less within 30 min. Timing is critical. Heating at 1400° F. and over is done either in inert atmospheres or by using suitable barrier coatings readily removable after treatment. Heating at 1050° F. ± 5° for 90 min. followed by air cooling ages the alloy. Furnaces must hold temperatures between ± 10° F. over effective hearth or chamber areas.

The treatments described provide ultimate strengths from 180,000 to 200,000 psi., elongation in 2 in. of 6% minimum and hardness of Rockwell C-40 to 45. Retreatment at 1075° F. ± 5° is permitted on parts which show higher hardness than desired after initial 1050° F. treatment. The 950° F. often suggested for 17-7 PH alloy is not recommended because of the increased susceptibility of material to intergranular corrosion and crack propagation.

In AM 350 alloy, the in-process annealing (between forming operations) is done at 1900° F. ± 50° for 5 to 10 min. Process annealing is done at 1710° F. ± 25° for 30 min. followed by air cooling. Hardening (cold treatment) is done at not less than −100° F. for 3 hr., and tempering at 850° F. ± 25° for 3 hr. follows. Air cooling then produces a material with a minimum ultimate strength of 185,000 psi., 10% elongation in 2 in. and Rockwell C-40 hardness. Hot alkaline immersion cleans the parts; they are then passivated in 18 to 30% HNO_3 and 6% HF for 3 to 5 min. Double aging is not done because of susceptibility to intergranular corrosion.

Warpage of 17-7 PH during processing is a problem, but some room-temperature straightening is possible. Flat sheets and formed parts of AM 350 will hold their shape if confined in fixtures during the −100° F. treatment. Parts made from thin material (when shape permits) can be wired together in groups for the cold treatment and will hold their shapes satisfactorily. Rusting of 17-7 PH and AM 350 is a problem especially in salt atmosphere, though no evidences of serious pitting and intergranular attack have been found.

A paper by L. H. McCreery, Chance Vought Aircraft, Inc., concerns 4340 heat treated to ultra high strengths. He showed that rigid controls during melting, casting,

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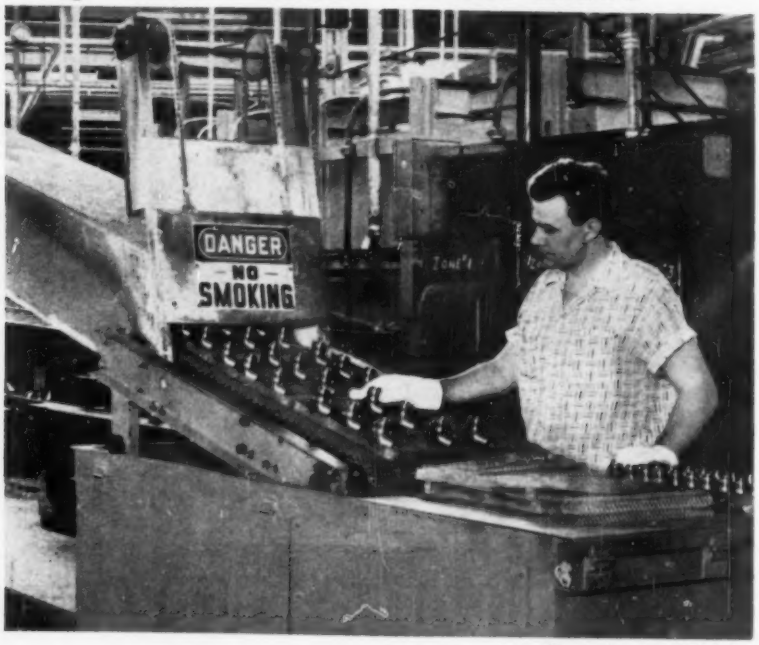

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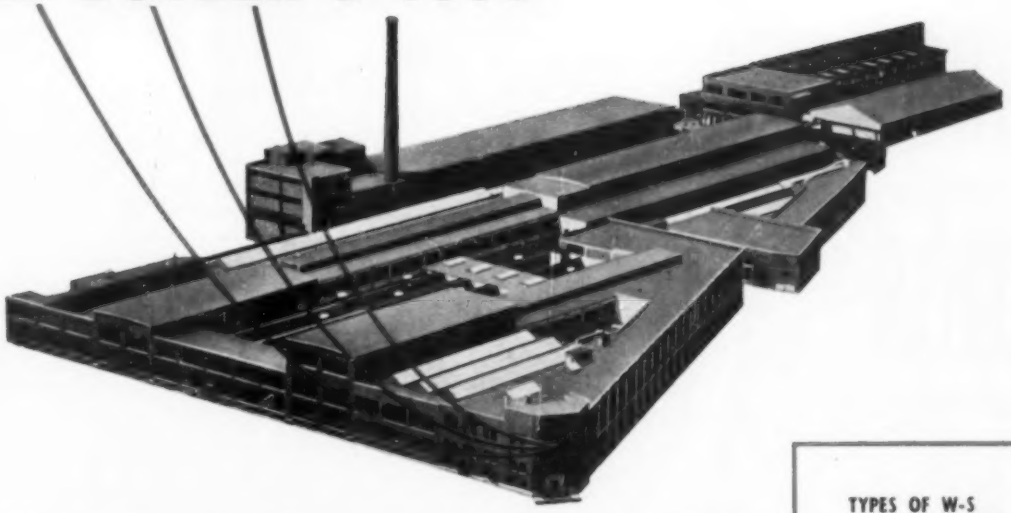

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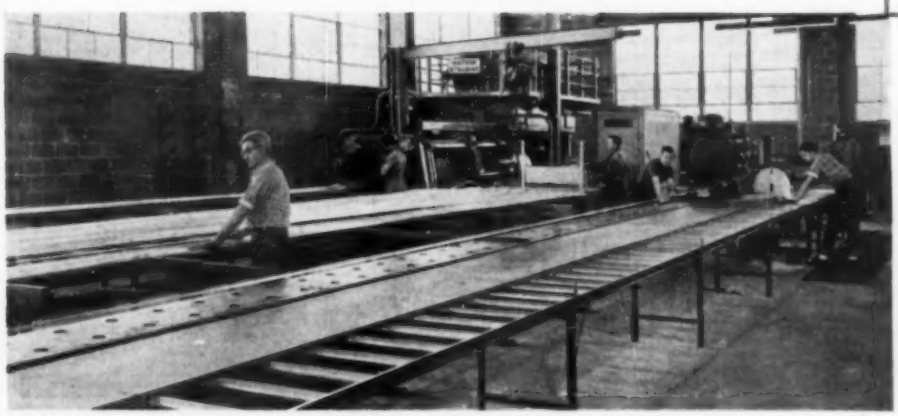

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Space Age . . .

forging, rolling and making of parts could produce minimum properties of 260,000 psi. ultimate strength, 240,000 psi. yield strength, 16% reduction of area, and 4.0% elongation in 2 in. The data presented showed that well-made and correctly processed material would provide transverse mechanical properties practically equivalent to longitudinal ones even comparing specimens from "center" and "outside."

This paper and others presented and discussed throughout these meetings are indicative of the many changes occurring in the aircraft industry. ARTHUR W. F. GREEN

Nodular Iron Welding Rod Containing Cerium

Digest of "A New Nodular Cast-Iron Welding Rod for Foundries and Fabricators", by R. O. Day, J. S. Snyder and H. V. Inskeep, *Welding Research Supplement*, Vol. 36, September 1957, p. 410s-414s.

SINCE its introduction as a new engineering material ten years ago, nodular cast iron has been the subject of numerous investigations to evaluate its properties and limitations. Notable among these limitations has been the undesirable hardening effect caused by rapid cooling from above the critical range. This condition has necessitated the employment of annealing treatments when the material is used for castings of light or thin section thickness, and until recently it has prevented the attainment of satisfactory mechanical properties in welded joints. A further difficulty encountered in welding has been the tendency toward reversion of the spherulitic graphite to flake graphite upon remelting and solidification.

The authors produced satisfactory nodular graphite structures and mechanical properties in welded specimens of nodular cast iron. Their results were accomplished through the use of a nodular cast iron filler rod with oxy-acetylene welding techniques. The filler rod is described as having a basic chemistry similar to that of the general run of unalloyed nodular cast iron, except that cerium rather than mag-

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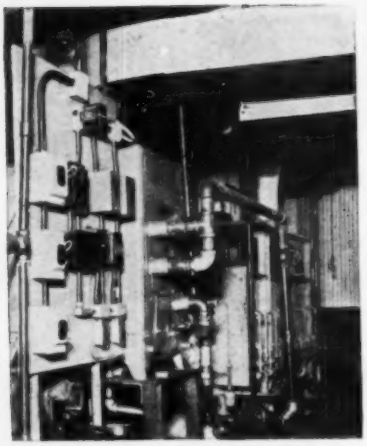

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The results of this work indicate the successful application of nodular cast iron as a filler rod which will produce welds in the 50,000 to 75,000 psi. ultimate tensile strength range, with elongations in the 5 to 10% range in the as-welded condition. At the present time the filler rod has been produced only on an experimental or pilot-plant basis. It is expected that techniques used to produce the experimental rod can be easily adapted to production operations. Meanwhile, it must be considered solely as an experimental item. W. W. AUSTIN

Low-Temperature Toughness of Welds for Storage Tanks

Digest of "Strength of Welded Joints in Vertical Tanks After Roll Bending", by B. F. Lebedev, *Automaticheskaya Svarka*, No. 1, 1956, p. 58-64.

FROM time to time brittle fractures have occurred in welded tanks for the storage of petroleum products and other liquids. While brittle failure is not completely understood, the

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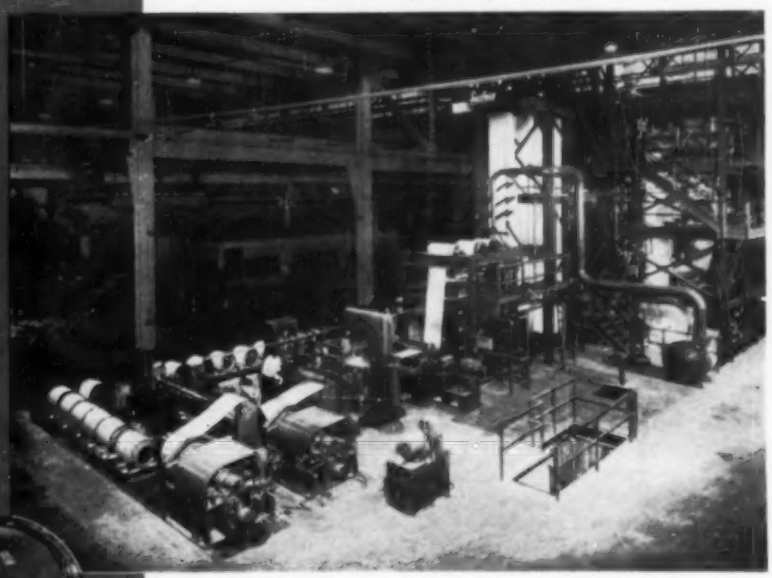

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mechanism arises from an unfavorable combination of stress concentration, shrinkage stresses and low temperature.

The first series of tests was made by the author to study the effect of residual welding stresses. Specimens were made of storage tank steel ⅜ in. thick. The test plate, 6¼ in. wide, contained a ⅜-in. longitudinal slot 18 in. long, in which a plate 2 in. wide was fillet welded. A narrow transverse cut in the 2-in. wide plate was made in the center of the specimen after welding. The cut served as a stress concentration. Half the specimens were submerged-arc welded manually with high-manganese flux OSTs 45; the other half were welded manually with UP-2/54 covered electrodes. Three specimens were stressed to 28,500 to 31,000 psi. at room temperature to remove residual welding stresses. The static tensile strength was determined at −4 to −76° F.

The specimens welded with covered electrodes without stress-relief had a tensile strength of 59,000 to 64,000 psi. at −4° F., but only 23,000 to 30,000 psi. at −40° F., and 10,000 to 42,000 psi. at −76° F. Specimens that had been mechanically stress-relieved had 59,000 to 65,000 psi. tensile strength at −22 to −76° F. Results were similar for the submerged-arc specimens, except that the tensile strength commenced to fall only at −58° F. All fractures were brittle. The results showed that residual welding stresses were responsible for low tensile strength at low temperature, and that the effect of residual stresses was more pronounced for covered electrodes than for submerged-arc welding.

To show the effect of intersecting welds on strength at low temperatures, specimens 9 in. wide with intersecting longitudinal and transverse butt welds were tested in static tension at −76° F. A stress concentration in the form of an unfused area was introduced in some of the specimens. With covered electrodes, the specimens with an unfused area, whether or not mechanically stress-relieved, had zero or very low elongation and failed in the weld. Without stress-relief and unfused areas, the elongation was 8.3 to 8.9%, the yield and tensile strengths being respectively 57,000 to 58,000 psi. and 76,000 to 83,000 psi. Failure occurred generally in the plate.

With submerged-arc welding, the elongation was 5.5 to 16.6% without stress-relief and unfused area, the yield and tensile strengths being about the same as with covered electrodes. With unfused areas, the elongation fell to 2.8 to 6.1%, but with stress-relief, elongation rose to 7.2 to 12.8%.

Roll bending of welded plates has been shown by X-ray measurements to reduce residual stresses in butt welds to one third of their initial value. To investigate the effect of roll bending on tensile strength, specimens 5/16 in. thick with intersecting submerged-arc welds containing unfused root areas 0.08 to 0.12 in. deep were made with and without roll bending to the curvature of storage tanks. There was little difference in the static tensile strength except at −76° F. At this temperature the tensile strength was only 47,500 psi. for the specimens without stress-relief, but was 61,000 to 71,000 psi. for specimens that had been mechanically stress-relieved in tension or by roll bending.

In a second series of specimens, ⅜ in. thick, a longitudinal butt joint was welded from both sides. A gap in the first layer was left in some specimens as a stress concentration. The results at −76° were similar to those of the preceding series.

The final series of specimens imitated conditions at the junction of wall with floor in a storage tank. A transverse butt weld in 5/16-in. plate was intersected by a fillet welded longitudinal plate. Tests were made only at −40° F. Again the superiority of the mechanically stress-relieved specimens was demonstrated. Low-temperature stress-relieving at 400 to 480° F. also provided good results, but its value in practice remains to be demonstrated.

The tests showed that relief of residual stresses raised the tensile strength at low temperatures. Submerged-arc welding gave higher strength at low temperatures than covered electrodes and is one of the weapons in the fight against brittle failure. Roll bending after welding also proved worthwhile.

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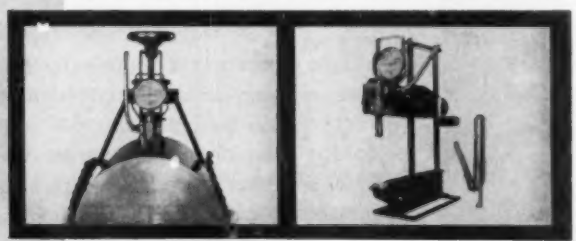

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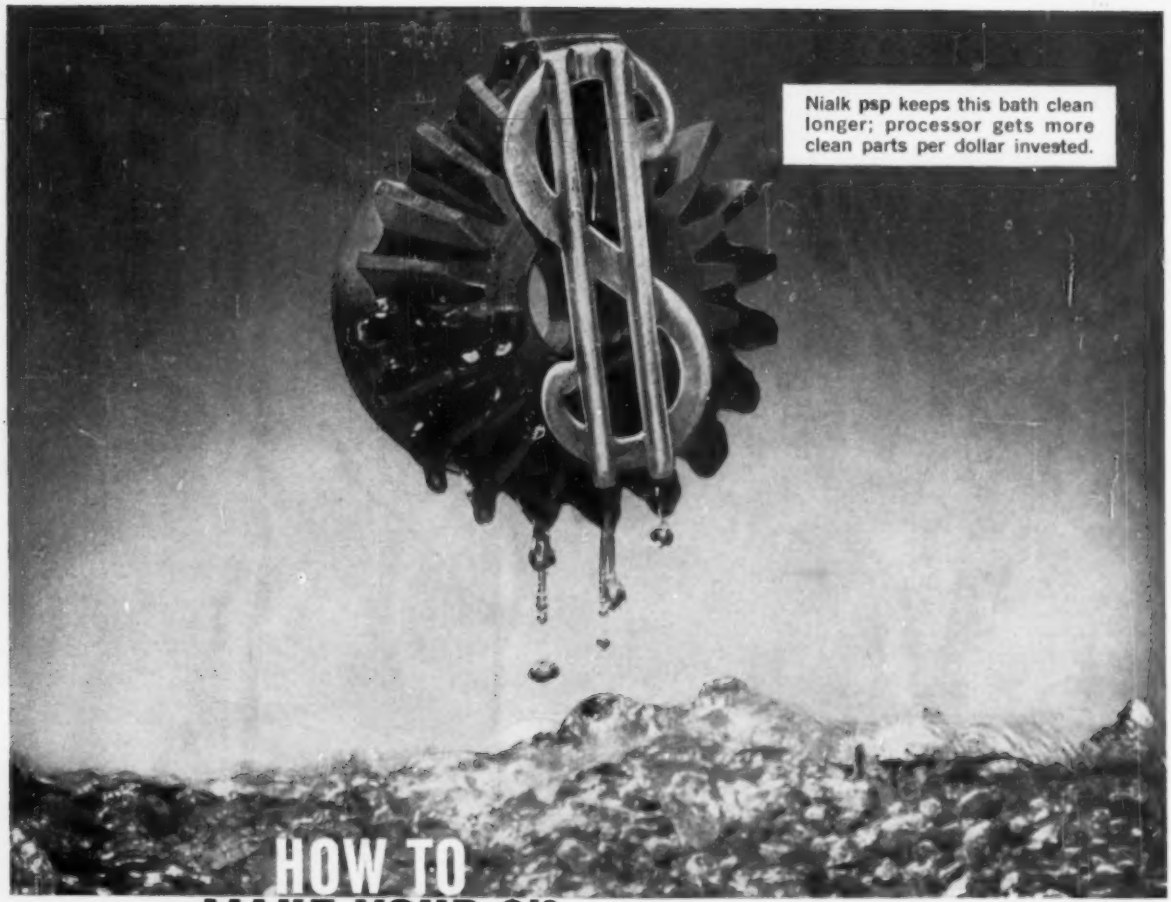

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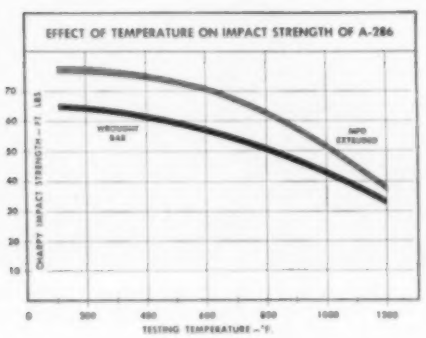

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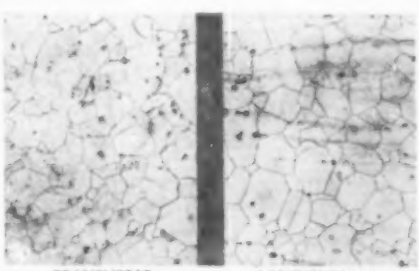

CURMET processing with accurate metallurgical control is typified by this microphoto of a precipitation hardening, high temperature alloy extrusion (A-286) showing uniform longitudinal and transverse grains. Metallurgical examination of the extrusion shows uniformity of microstructure, assuring consistently high mechanical properties throughout the full length.

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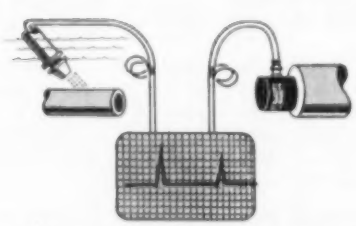

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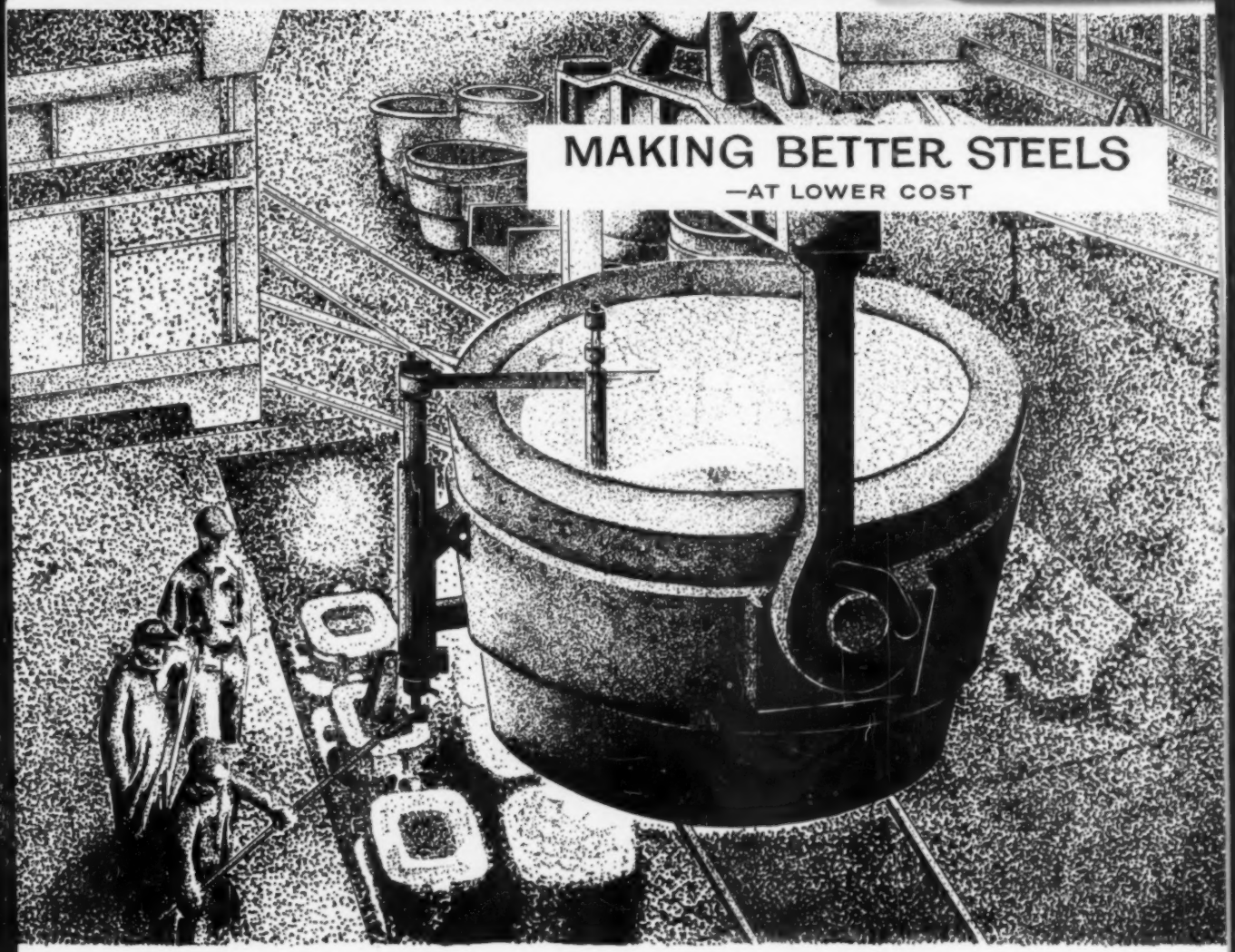

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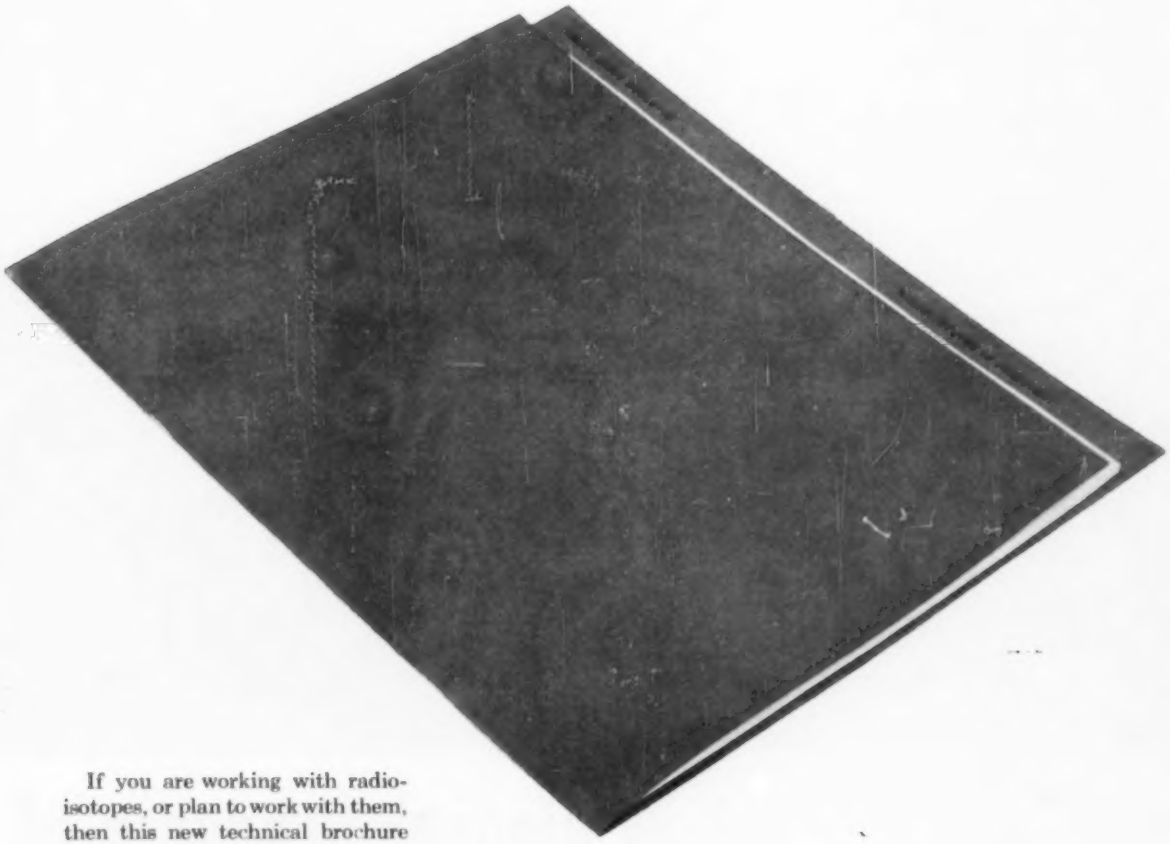

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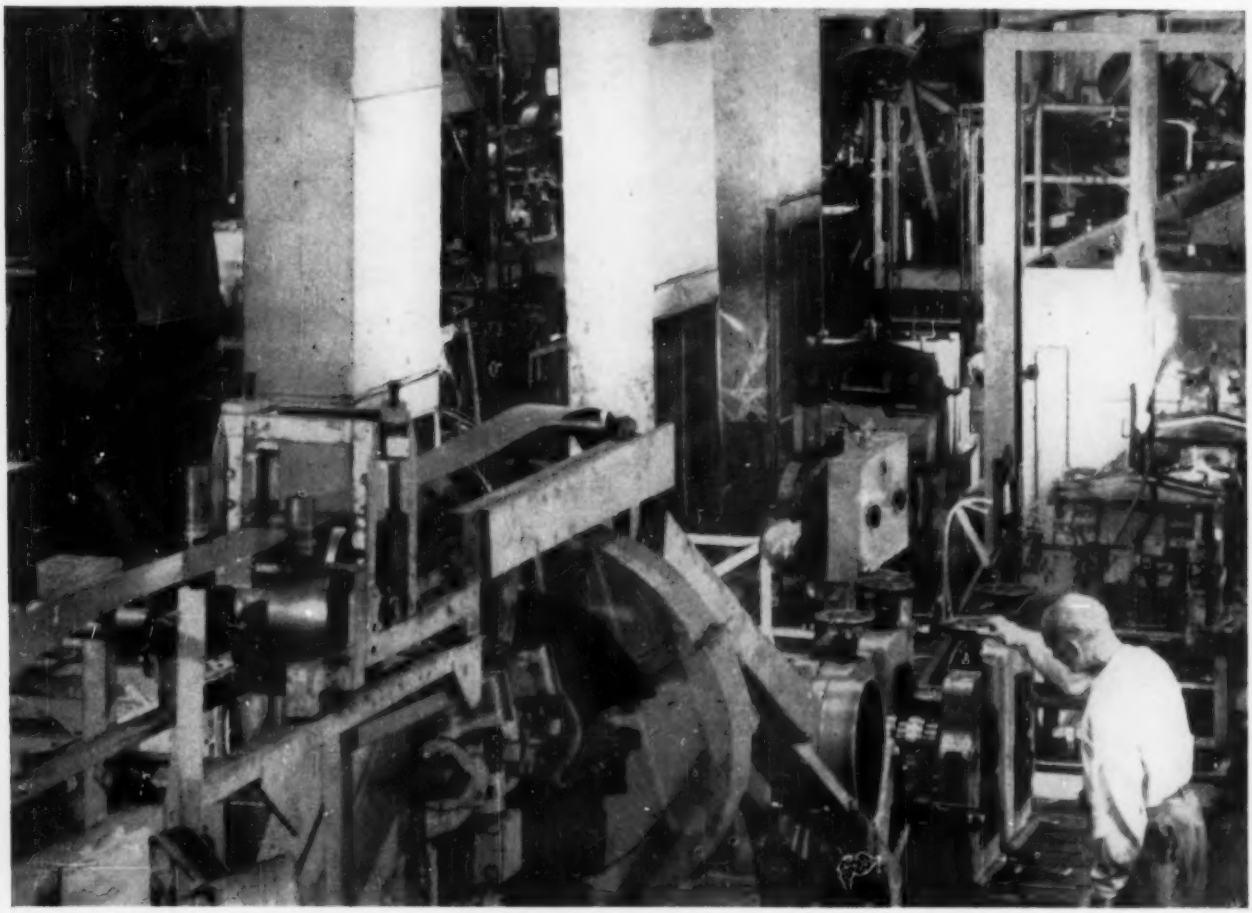

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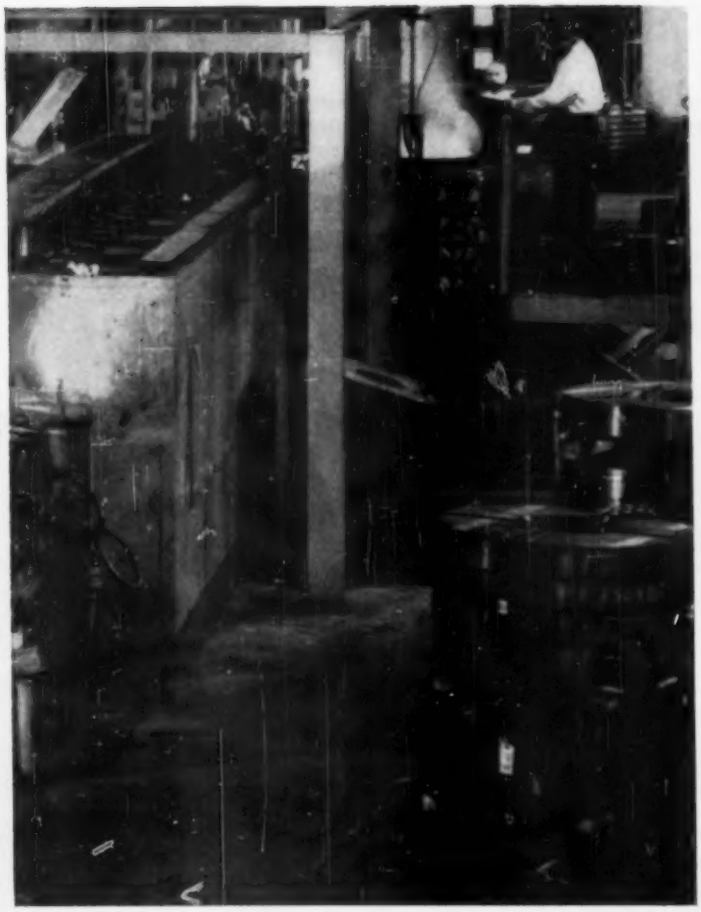

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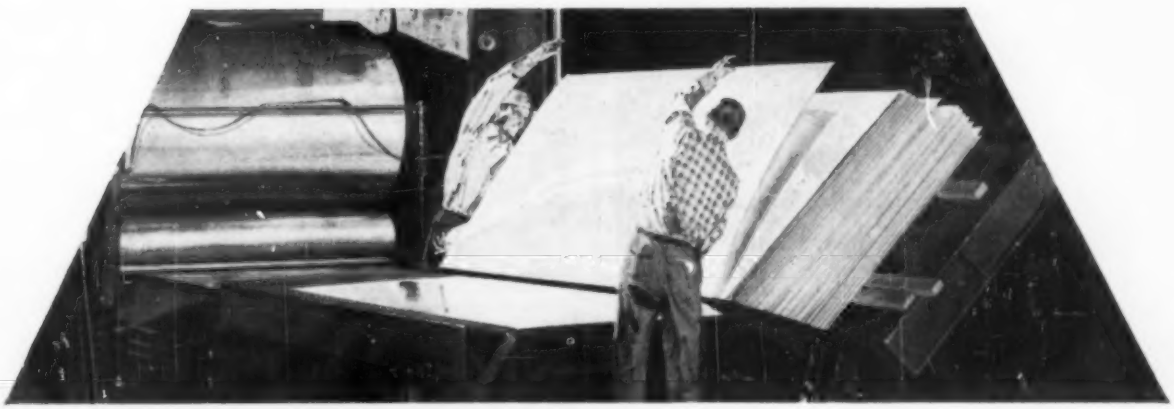

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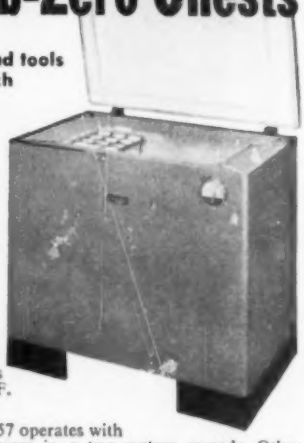

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			Rm. 70°	Rm. 110°	L	W	H	L	W	H
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Sub-Zero	SZH653	6.5	–85° F.	–75° F.	60"	28"	42¾"	47"	15"	16"
Sub-Zero	SZHC657	6.5	–140° F.	–125° F.	60"	28"	42¾"	47"	15"	16"
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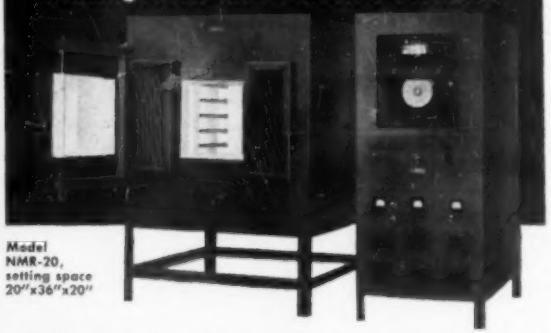

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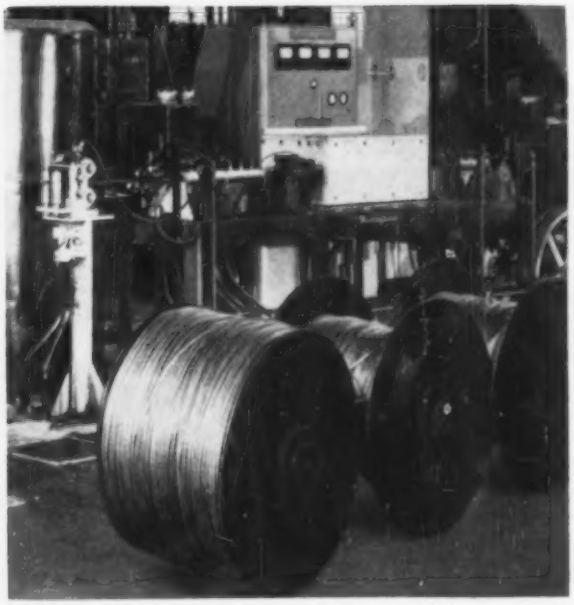

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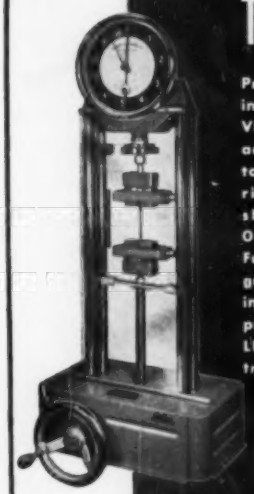

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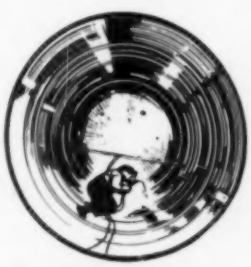

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